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Sept. 19, 1927

PHYSIOLOGY AND HYGIENE

FOR

SECONDARY SCHOOLS

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"It is quite possible to give instruction in this subject in such a manner as not only to confer knowledge which is useful in itself, but to serve the purpose of a training in accurate observation, and in the methods of reasoning of physical science." — *Huxley.*

REVISED

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PREFACE TO FIRST EDITION

(ABRIDGED)

The aim in the preparation of this treatise on the human body has been, first, to set forth in a *teachable* manner the actual science of physiology; and, second, to present the facts of hygiene largely as *applied physiology*. The view is held that "right living" consists in the harmonious adjustment of one's habits to the nature and plan of the body, and that the best preparation for such living is a correct understanding of the physical self.

Although no effort has been spared to bring this work within the comprehension of the pupil, its success in the classroom will depend largely upon the method of handling the subject by the teacher. It is recommended, therefore, that the *relations* which the different organs and processes sustain to each other, and to the body as a whole, be given special prominence. The pupil should be impressed with the essential unity of the body and should see in the diversity of its activities the serving of a common purpose. In creating such an impression the introductory paragraphs at the beginning of many of the chapters and the summaries throughout the book, as well as the general arrangement of the subject matter, will be found helpful.

While the method of teaching that uses the pupil's experience as a basis on which to build is not to be discounted, we must recognize *the inadequacy of this experience as it pertains to the body*. It cannot supply a sufficient foundation for a science such as physiology. Herein lies

the need for experiments and observations. They supplement the pupil's experience and increase both the number and definiteness of his ideas. No great degree of success can be attained if this phase of the study is omitted.

The best results in physiology teaching are of course attained where laboratory work is carried on by the pupils, but where this cannot be arranged, class experiments and observations must suffice. The Practical Work described at the close of most of the chapters is mainly for class purposes. While this serves a necessary part in the development of the subject, it is not essential that all of the experiments and observations be made, the intention being to provide for some choice on the part of the teacher.

To adapt the book to as wide a range of usefulness as possible, more subject matter is introduced than is usually included in an elementary course. Most of the portions, however, that are unessential to a proper understanding of the body by the pupil are set in small type, to be used at the discretion of the teacher.

In the preparation of this work valuable assistance has been rendered by President W. J. Hawkins, Dr. C. N. McAllister, and Professor B. M. Stigall of the Warrensburg, Missouri, State Normal School; by Professor S. D. Magers of the Ypsilanti, Michigan, State Normal School; and by Professors C. H. Nowlin, John W. Scott, and A. E. Shirling of the Kansas City, Missouri, High Schools. To these and many others the author makes grateful acknowledgment.

F. M. W.

PREFACE TO REVISED EDITION

This edition presents a thorough revision of this book without alteration of its essential plan, as stated in the preface to the first edition. Special effort has been made, however, to incorporate such advances in practical hygiene teaching as have been recently made. To this end all the subject matter on hygiene has been rewritten and eight new chapters added.

In these chapters the general view that "right living consists in the harmonious adjustment of one's habits to the nature and plan of the body" is maintained and the effects of right and wrong living explained in considerable detail. Right living, in a general way, means *living right in particular ways that affect the bodily organs and processes.* We must so live that beneficial effects are manifest in the bodily shape, in the condition of the muscles, in the state of the digestion, in the circulation of the blood, in the working of the mind and the nervous system, and in other matters of physiological functioning. In short, right living means everything that the individual must do or supply, in order to bring the body organization to its highest state of efficiency.

It is generally conceded that a sustained interest on the part of the pupil in matters of health should be a chief aim of every course in hygiene. Although the author has had this in mind in carrying the idea of right living entirely through the book, he feels that a great opportunity both for the development of interest and for health betterment

will be lost, if *health-building work* is not required of each member of the class. While this will necessitate one or more simple physical examinations, the assignment of definite health problems to each one, and the giving of a health grade, the results will more than compensate for the extra effort that is entailed.

For supplementing the work both in the physiology and the hygiene, the use of books of reference is earnestly recommended. The following advanced works should be in the school library and frequently consulted: Howell's *A Text-book of Physiology*, Burton-Opitz' *An Elementary Physiology*, Stiles' *Human Physiology*, Hough and Sedgwick's *The Human Mechanism*, Fisher and Fisk's *How to Live*, Pyle's *Personal Hygiene*, Overton and Denno's *The Health Officer*, Galbraith's *Personal Hygiene and Physical Culture for Women*, Williams' *Personal Hygiene Applied*, and Walters' *Principles of Health Control*.

The author would take advantage of the present opportunity to express his appreciation for the kindly criticisms that have come to him from the teachers who have used the first edition in their classes. He sincerely hopes that the present edition meets their approval in every respect.

F. M. W.

Central Missouri State Teachers' College,
January 1, 1924.

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PHYSIOLOGY AND HYGIENE

PART I: INTERNAL BODILY WORK OR VITAL PROCESSES

CHAPTER I

INTRODUCTION

To derive strength equal to the daily task; to experience the advantages of health and avoid the pain, inconvenience, and danger of disease; to live out contentedly and usefully the natural span of life: these are problems that concern all people. They are, however, but different phases of one great problem — the problem of properly managing or caring for the body. To supply knowledge necessary to the solution of this problem is the chief reason why the body is studied in our public schools.

Divisions of the Subject. — The body is studied from three standpoints: structure, use of parts, and care or management. This causes the main subject to be considered under three heads, known as anatomy, physiology, and hygiene.

Anatomy treats of the construction of the body — the parts which compose it, what they are like, and where located. Its main divisions are known as gross anatomy and histology. *Gross anatomy* treats of the larger structures of the body, while *histology* treats of the minute structures of which these are composed — parts too small to be seen

with the naked eye and which have to be studied with the aid of the microscope.

Physiology treats of the function, or use, of the different parts of the body — the work which the parts do and how they do it — and of their relations to one another and to the body as a whole.

Hygiene treats of the proper care or management of the body. It is said to be *personal* when applied by the individual to himself, and *general* when applied to the community or to the race as a whole. *Corrective Hygiene* is a phase of personal hygiene in which one seeks to build up parts of his body that are weak or to put his health on a higher plane.

The General Aim of Hygiene. — This is expressed in two short words — *right living*. Right living is living in such a way that the body is benefited, and not injured, by the various things that affect it. As we study the body we find that it is a rather delicate structure which is affected by different things. It is affected by what goes into it, by what it does, by clothing and footwear, by climate, by the house in which one lives, by the bed in which one sleeps, by the people with whom he associates, and by many other things. These all can have good effects upon the body and effects that are bad. Right living secures each day the effects that are beneficial and avoids the effects that are harmful.

Wrong Living and its Effects. — Wrong living is living in such manner that the various things that affect the body produce harmful instead of beneficial results. One may live wrongly with reference to his food, his clothing, his work, or anything else that has any effect upon him. And the harm that results may come about gradually or it may be a cause for the quick development of some kind of

sickness, or disease. In some cases the results of wrong living do not show until one is well along in life.

Rewards of Right Living. — These are too numerous to mention all of them. On the one hand, right living prevents the loss of whatever health we may already have, and on the other hand, it enables us to build up or improve our health from day to day. As we build up our health, we become better workers in whatever we undertake to do; we are happier and are more capable of making others happy; and we are more interesting and attractive to those about us. Then if we continue to live rightly, we will increase the number of years which we are to spend here on earth and will make the last of life enjoyable and profitable.

Exercises. — 1. For what purpose is the body studied in our public schools?

2. Under what three heads is it studied? Define each.

3. When is hygiene said to be personal? When general? When corrective?

4. Compare right living and wrong living with reference to their effects upon the body.

5. Discuss the rewards of right living.

CHAPTER II

GENERAL VIEW OF THE BODY

External Divisions. — Examined from the outside, the body presents certain parts, or divisions, familiar to all. The main, or central, portion is known as the *trunk*, and to this are attached the *head*, the *upper extremities*, and the *lower extremities*. These in turn present smaller divisions which are also familiar. The upper part of the trunk is known as the *thorax*, or chest, and the lower part as the *abdomen*. The portions of the trunk to which the arms are attached are the *shoulders*, and those to which the legs are joined are the *hips*, while the central rear portion between the neck and the hips is the *back*. The fingers, the hand, the wrist, the forearm, the elbow, and the upper arm are the main divisions of each of the upper extremities. The toes, the foot, the ankle, the lower leg, the knee, and the thigh are the chief divisions of each of the lower extremities. The head, which is joined to the trunk by the neck, has such interesting parts as the eyes, the ears, the nose, the jaws, the cheeks, and the mouth. The entire body is inclosed in a double covering, called the *skin*, which protects it in various ways.

The Tissues. — After examining the external features of the body, we naturally inquire about its internal structures. These are not so easily investigated, and much which is of interest to advanced students must be omitted from an elementary course. We may, however, as a first step in this study, determine what kinds of materials enter into

the construction of the body. For this purpose the body of some small animal should be dissected and studied. (See observation at close of chapter.) The different materials found by such a dissection correspond closely to the substances, called *tissues*, which make up the human body. The main tissues of the body, as ordinarily named, are the *muscular* tissue, the *osseous* tissue, the *connective* tissue, the *nervous* tissue, the *adipose* tissue, the *cartilaginous* tissue, and the *epithelial* and *glandular* tissue. Most of these present different varieties, making all together some fifteen different kinds of tissues that enter into the construction of the body.[1]

General Purposes of the Tissues. — The tissues, first of all, *form the body.* As a house is constructed of wood, stone, plaster, iron, and other building materials, so is the body made up of its various tissues. For this reason the tissues have been called the *building materials* of the body.

In addition to forming the body, the tissues supply the means through which its work is carried on. They are thus the *working materials* of the body. In serving this purpose the tissues play an active rôle. All of them must perform the activities of growth and repair, and certain ones (the so-called active tissues) must do work which benefits the body as a whole.

Purposes of the Different Tissues. — In the construction of the body and also in the work which it carries on, the different tissues are made to serve different purposes. The osseous tissue is the chief substance in the bony framework, or skeleton, while the muscular tissue produces the different movements of the body. The connective

[1] When classified according to their essential structure, the tissues fall into four main groups: epithelial and glandular tissue, muscular tissue, nervous tissue, and connective tissue. According to this system the osseous, cartilaginous, and adipose tissues are classed as varieties of connective tissue.

tissue, which is everywhere abundant, serves the general purpose of connecting the different parts together. Cartilaginous tissue forms smooth coverings over the ends of the bones and, in addition to this, supplies the necessary stiffness in organs like the larynx and the ear. The nervous tissue controls the body and brings it into proper relations with its surroundings, while the epithelial tissue (found upon the body surfaces and in the glands) supplies it with protective coverings and secretes liquids. The adipose tissue (fat) prevents the too rapid escape of heat from the body, supplies it with nourishment in time of need, and forms soft pads for delicate organs like the eyeball.

Properties of the Tissues. — If we inquire how the tissues are able to serve such widely different purposes, we find this answer. The tissues differ from one another both in composition and in structure and, on this account, differ in their properties.[1] Their different properties enable them to serve different purposes in the body. Somewhat as glass is adapted by its transparency, hardness, and toughness to the use made of it in windows, the special properties of the tissues adapt them to the kinds of service which they perform. Properties that adapt tissues to their work in the body are called *essential* properties. The most important of these essential properties are as follows:

1. Of osseous tissue, hardness, stiffness, and toughness. 2. Of muscular tissue, contractility and irritability. 3. Of nervous tissue, irritability and conductivity. 4. Of cartilaginous tissue, stiffness and elasticity. 5. Of connective tissue, toughness and pliability. 6. Of epithelial tissue, ability to resist the action of external forces and power to secrete.

[1] The properties of substances are the qualities or characteristics (color, weight etc.) by means of which they are recognized.

Tissue Groups. — In the construction of the body the tissues are grouped together to form its various divisions or parts. A group of tissues which serves some special purpose is known as an *organ.* The hand, for example, is an organ for grasping (Fig. 1). While the different organs of the body do not always contain the same tissues, and never contain them in the same proportions, they do contain such tissues as their work requires and these have a special arrangement — one adapted to the work which the organs perform.

In addition to forming the organs, the tissues are also grouped in such a manner as to provide supports for organs and to form cavities in which organs are placed. The various cavities of the body are of particular interest and importance. The three largest ones are the *cranial* cavity, containing the brain; the *thoracic* cavity, containing the heart and the lungs; and the *abdominal* cavity, containing the stomach, the liver, the intestines, and other important organs (Fig. 2). Smaller cavities serving different purposes are also found.

FIG. 1. — **Hand and forearm,** showing the grouping of muscular and connective tissues in the organ for grasping.

Organs and Systems. — The work of the body is carried on by its various organs. Many, in fact the majority, of these organs serve more than one purpose. The tongue

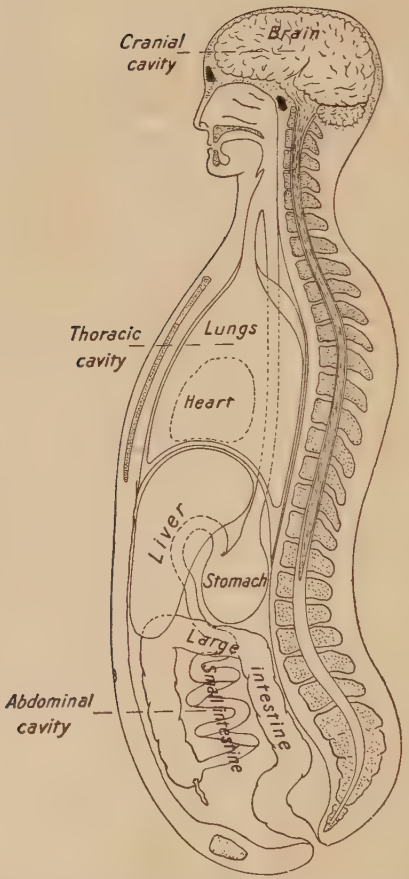

FIG. 2. — **Diagram of a lengthwise section of the body** to show its large cavities and the organs which they contain.

is used in talking, in masticating the food, and in swallowing. The nose serves at least three distinct purposes. The mouth, the arms, the hands, the feet, the legs, the liver, the lungs, and the stomach are also organs that serve more than one purpose. This introduces the principle of economy into the construction of the body and diminishes the number of organs that would otherwise be required.

The various organs also *combine* with one another in carrying on the work of the body. An illustration of this is seen in the digestion of the food — a process which requires the combined action of the mouth, stomach, liver, intestines, and other organs. A number of organs working together for the same purpose form a *system*. The chief systems of the body are the digestive system, the circulatory system, the respiratory system, the muscular system, and the nervous system.

The Organ and its Work. — A most interesting question relating to the work of the organ is this: Does the organ work for its own benefit or for the benefit of the body as a whole? Does the hand, for example, grasp for itself or in order that the entire body may come into possession? Only slight study is sufficient to reveal the fact that each organ performs a work which benefits the body as a whole. In other words, just as the organ itself is a part of the body, the work which it does is a part of the necessary work which the body has to do.

But in working for the general good, or for the body as a whole, each organ becomes a sharer in the benefits of the work done by every other organ. While the hand receives only a little of the nourishment contained in the food which it places in the mouth or of the heat from fuel which it places on the fire, it is aided and supported by the work of all the other organs of the body — eyes,

feet, brain, heart, etc. The hand does not and cannot work independently of the other organs. It is one of the partners in a very close combination where, by doing a particular work, it shares in the profits of all. What is true of the hand is true of every other organ of the body.

What Shall we Call the Body? — Different names, such as "the house in which we live," "the human machine," and "the human city," have been applied to the body as it has been studied from different standpoints. When we think of its different parts and the way they work together, another name seems especially appropriate. This is the name *organization*. An organization is properly defined as any group of individuals which, in working together for a common purpose, practices *division of labor*.[1] Other reasons for looking upon the body as an organization will be brought out in the next chapter.

Summary. — Viewed from the outside, the body is seen to be made up of divisions which are more or less familiar. Viewed internally, it is found to consist of different kinds of materials, called *tissues*. The tissues are adapted, by their properties, to different purposes both in the construction of the body and in carrying on its work. The working parts of the body are called organs and these in their work combine to form systems. The entire body, on account of the method of its construction and the character of its work, may be classed as an organization.

Exercises. — 1. Name and locate the chief external divisions of the body.

2. What tissues may be found by dissecting the leg of a chicken?

3. Name the most important properties and the most important uses of muscular tissue, osseous tissue, and connective tissue.

4. Define an organ. Define a system. Name examples of each.

[1] People in working together practice *division of labor* when one person does one thing and another person does another.

5. Name the chief cavities of the body and the organs which they contain.

6. What tissues are present in the hand? How does each of these aid in the work of the hand?

7. Name the uses of the tongue. What is the advantage of having one organ do more than one thing?

8. Why may we refer to the different organs as partners?

9. Define an organization. Explain the phrase "division of labor."

PRACTICAL WORK

Observation on the Tissues. — Examine with care the structures in the entire leg of a chicken, squirrel, rabbit, or other small animal used for food. Observe, first of all, the external covering, consisting of cuticle and hair, claws, scales, or feathers, according to the specimen. These are similar in structure, and they form the epidermis, which is one kind of *epithelial* tissue. With a sharp knife lay open the skin and observe that it is attached to the parts underneath by thin, but tough, threads and sheaths. These represent a variety of *connective* tissue. The reddish material which forms the greater portion of the specimen is a variety of *muscular* tissue, and its divisions are called muscles. With a blunt instrument, separate the muscles, by tearing apart the connective tissue binding them together, and find the glistening white strips of connective tissue (tendons) which attach them to the bones. Find near the central part of the leg a soft, white cord (a nerve) which represents one variety of *nervous* tissue. The bones, which may now be examined, form the *osseous* tissue. At the ends of the bones will be found a layer of smooth, white material which represents one kind of *cartilaginous* tissue. The *adipose*, or fatty, tissue, which is found under the skin and between the other tissues, is easily recognized.

CHAPTER III

THE BODY ORGANIZATION

WHAT is the nature of the body organization? What are the individual parts, or units, that make it up? What general work do these carry on and upon what basis do they practice the division of labor? The answers to these questions will suggest the main problems in the study of the body.

Complex Nature of the Tissues. — To the unaided eye the tissues have the appearance of simple structures. The microscope, however, shows just the reverse to be true. When any one of the tissues is suitably prepared and carefully examined with this instrument, at least two classes of materials can be made out. One of these consists of minute particles, called *cells;* the other is a substance lying between the cells, known as the *intercellular material* (Fig. 3). The cells and the intercellular material, though varying in their relative amount, are present in all the tissues.

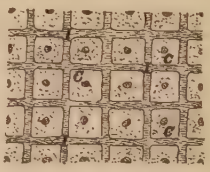

FIG. 3. — **Diagram** showing the relation of the cells and the intercellular material. *C.* Cells. *I.* Intercellular material.

The Body a Cell Group. — The biologist has found that the bodies of all living things, plants as well as animals, consist either of single cells or of groups of cells. The single cells live independently of one another, but the cells that form groups are attached to, and are more or less dependent upon, one another. In the first condition are

found the very lowest forms of life. In the second, life reaches its greatest development. The body of man, which represents the highest type of life, is recognized as a group of cells. In this group each cell is usually separate and distinct from the others, but is attached to them, and is held in place by the intercellular material.

Protoplasm, the Cell Substance. — The cell is properly regarded as an *organized* bit of a peculiar material, called *protoplasm*. This is a semi-liquid and somewhat granular substance which resembles in appearance the white of a raw egg. Its true nature and composition are unknown, because any attempt to analyze it kills it, and dead protoplasm is essentially different from living protoplasm. It is known, however, to be a highly complex substance and to undergo chemical change readily. It appears to be the only kind of matter with which life is ever associated, and for this reason protoplasm is called the *physical basis of life*. Its organization into separate bits, or cells, is necessary to the life activities that take place within it.

Structure of the Cell. — Though all portions of the cell are formed from the protoplasm, this essential substance differs both in structure and in function at different places in the cell. For this reason the cell is looked upon as a complex body having several distinct parts. At or near the center is a clear, rounded body, called the *nucleus*. This plays some part in the nourishment of the cell and also in the formation of new cells. If it be absent, as is sometimes the case, the cell is short-lived and unable to reproduce itself. The variety of protoplasm contained in the nucleus is called the *nucleoplasm*.

Surrounding the nucleus is the *main body* of the cell, sometimes referred to as the "protoplasm." Since the

protoplasm forms all parts of the cell, this substance is more properly called the *cytoplasm*, or cell plasm. Surrounding and inclosing the cytoplasm, in many cells, is a thin outer layer, or membrane, which affords more or less protection to the contents of the cell. This is usually referred to as the *cell-wall*. A fourth part of the cell is also described, being called the *attraction sphere*. This is a small body lying near the nucleus and coöperating with that body in the formation of new cells. Food particles, wastes, and other substances may also be present in the cytoplasm. The parts of a typical cell are shown in Fig. 4.

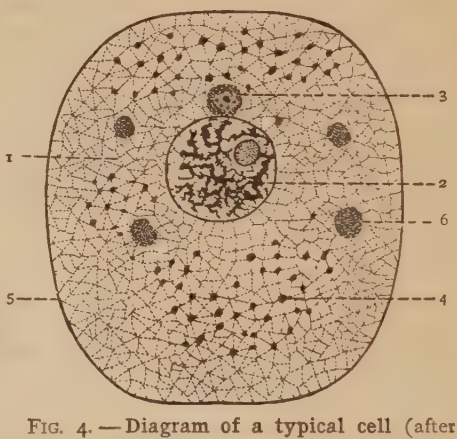

FIG. 4. — **Diagram of a typical cell** (after Wilson). 1. Main body. 2. Nucleus. 3. Attraction sphere. 4. Food particles and waste. 5. Cell-wall. 6. Masses of active material found in certain cells, called plastids.

Importance of the Cells. — The cells must be regarded as the living, working parts of the body. They are the active agents in all of the tissues, enabling them to serve their various purposes. Working through the tissues, they build up the body and carry on its different activities. They are recognized on this account as *the units of structure and of function*, and are the "individuals" in the body organization. Among the most important and interesting of the activities of the cells are those by which they build up the body, or cause it to grow.

How the Cells enable the Body to Grow. — Every cell is able to take new material into itself and to add this to the protoplasm. This tends to increase the amount of the protoplasm, thereby causing the cells to increase in size. A general increase in the size of the cells has the effect of increasing the size of the entire body, and this is one way by which they cause it to grow. There is, however, a fixed limit, varying with different cells, to the size which they attain, and this is quite low. (The largest cells are scarcely visible to the naked eye.) Any marked increase in the size of the body must, therefore, be brought about by other means. Such a means is found in the formation of new cells, or *cell reproduction*. The new cells are always formed *by* and *from* the old cells, the essential process being known as *cell-division*.

Cell-Division. — By dividing, a single cell will, on attaining its growth, separate into two or more new cells. The

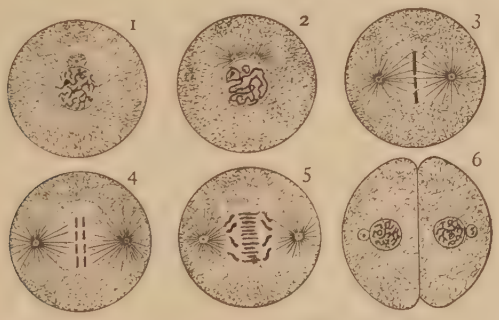

FIG. 5. — **Steps in cell-division** (after Wilson). Note that the process begins with the division of the attraction sphere, then involves the nucleus, and finally separates the main body.

process is quite complex and is imperfectly understood. It is known, however, that the act of separation is preceded by a series of changes in which the attraction sphere

and the nucleus actively participate, and that, as a result of these changes, the contents of the old cell are rearranged to form the new cells. Some of the different stages in the process, as they have been studied under the microscope, are indicated in Fig. 5.

Gradually, through the formation of new cells and by the growth of these cells after they have been formed, the body attains its full size. When growth is complete, cell reproduction is supposed to cease except where the tissues are injured, as in the breaking of a bone, or where cells, like those at the surface of the skin, are subject to wear. New material, however, is added to the protoplasm in the cells throughout life, but in amounts only sufficient to replace what is lost as waste.

FIG. 6. — **A tumbler** partly filled with marbles covered with water, suggesting the relations of the cells to the lymph.

Cell Surroundings. — All cells are said to be *aquatic*. This means simply that they require water for carrying on their various activities. The cells, in order to live, must take in and give out materials, and water is necessary to both processes. It is also an essential part of the protoplasm. Deprived of water, cells become inactive and usually die. Aquatic surroundings are provided for the cells of the body through a liquid known as the *lymph*, which is distributed throughout the intercellular material (Fig. 6). This consists of water containing oxygen and food substances in solution. Besides supplying these to the cells, the lymph also receives their wastes. Through the lymph the necessary conditions for cell life are provided in the body.

The General Work of Cells. — In handling the materials

obtained from the lymph, the cells carry on four kinds of work, or processes, as follows:

1. *A taking in process,* called *absorption.* Each cell absorbs food, oxygen, and water from the surrounding lymph.

2. *An adding to process,* called *assimilation.* The absorbed material is added to the protoplasm or so arranged that it is ready for use.

3. *A using up process,* called *oxidation.* In this process oxygen unites with other materials in the cells and sets free heat and bodily power, or energy.

4. *A throwing off process,* called *excretion.* Waste formed by oxidation and other changes is passed from the cells into the lymph and thence to the outside of the body.

Absorption, assimilation, oxidation, and excretion are carried on by all classes of cells. They are, on this account, referred to as the *general work* of the cells. The general work of the cells benefits them individually.

The Special Work of Cells. — In addition to the general work which all cells do in common, each class of cells in the body is able to do some particular kind of work — a work which the others cannot do or which they can do only to a limited extent. This is spoken of as the *special work of cells.* Examples of the special work of cells are found in the production of motion by muscle cells and in the secretion of liquids by gland cells. It may be noted that while the general work of cells benefits them individually, their special work benefits the body as a whole.

Nature of the Body Organization. — The work done by the different organs, as shown in the preceding chapter, is in reality carried on by the cells. To see that this is true, we have only to observe the relation of cells to tissues and of tissues to organs. The cells form the tissues and the

tissues form the organs. This arrangement enables the special work of different kinds of cells to be combined in the work of the organ as a whole. This is seen in the hand which, in grasping, uses motion supplied by the muscle cells, a controlling influence supplied by the nerve cells, a framework supplied by the bone cells, and so on. The cells supply the basis for the body organization and, properly speaking, the body is *an organization of cells*.[1]

Purpose of the Body Organization. — In any organization there is a common purpose toward which all the individual parts work. The purpose in the cell organization, called the body, is to supply conditions whereby all the cells can live and keep healthy. In carrying out this purpose, the cells, and the tissues and organs which they form, are organized, or arranged, to carry on two distinct kinds of work:

1. An internal work by which there is prepared, maintained, and circulated, a *nutrient fluid* for the benefit of the cells. The different kinds of work carried on for this purpose are referred to as the *vital processes*.

2. An external work whose purpose is to supply material for the nutrient fluid, protect the whole body, and in other ways keep it in right relations with its surroundings.

For doing its internal work the body has its organs of circulation, digestion, respiration, and excretion, and important glands outside of these. For doing its external work the body has its external organs — hands and arms, feet and legs, and eyes, ears, and other organs of sense. In Chapter V we begin the study of the body's internal work.

[1] Any organized structure, such as the body, whose parts are pervaded by a common life, is known as an *organism*. The term "organism" is frequently applied to the body.

Summary. — The individual parts, or units, that form the body organization are known as cells. These are minute bodies with definite parts which are held together by the intercellular material. The cells build up the body and carry on its different kinds of work. In doing this, like cells are grouped together to form the tissues out of which all the bodily parts are constructed.

Exercises. — If a tissue be compared to a brick wall, to what do the separate bricks correspond? To what the mortar between the bricks?

2. Draw an outline of a typical cell, locating and naming its main divisions.

3. How do the cells cause the body to grow? Describe the process of cell-division.

4. How does the general work of cells differ from their special work?

5. Define absorption, assimilation, oxidation, and excretion as applied to the cells.

6. For what common purpose do all the cells strive? In carrying out this purpose why must they practice "division of labor"?

7. Compare the work of external and internal organs.

CHAPTER IV

RIGHT LIVING AND THE CELLS

If we are living rightly, all of our cells are being benefited. If we are living wrongly, some or all of them are being injured. Proof for these statements is found in the nature of the body itself.

Health and Sickness Both Conditions of the Cells. — The work of the cells does not stop with the different things that are done by the organs and the systems. There are several other things that can be traced back to the cells, and one of these is the general condition of the body which we call health. The great difference between good health and disease, or sickness, is explained by differences in the condition of the cells at different times and the way some or all of them are working. In general we may say that *good health is the condition of the body when all the cells are healthy and are doing their work in a proper manner*, and that poor health is the opposite condition. Our methods of living can only affect our health (p. 2) as they have some effect upon our cells.

To get some idea of the kind of living that is beneficial to our cells, we must study the methods by which the body itself cares for them.

How the Body Cares for the Cells. — The body organization as it carries on the two lines of work described in the last chapter, is constantly doing many things for the benefit of the cells, as follows:

It provides room for all of them and keeps each one where it belongs. The cells must not be crowded together too much and they must not be pressed upon by things from the outside.

It supplies movement for the cells — movement of the whole body from place to place, movement of one part upon another, and movement of materials all through the body.

It produces, collects, and prepares food for the cells and sends this to them in all parts of the body.

It separates oxygen from the air and sends this to all the cells.

It gathers up the waste formed by the cells and removes this from the body.

It gives all the different cells some kind of work, or exercise, so that they can develop and keep strong.

It controls the cells so that they do the right things at the right time and do not injure each other.

It protects them in various ways.

Right living is the kind of living that aids the body in doing all these different things for the cells.

General Aims in Right Living. — Although right living includes a great many things, these can all be grouped under three main heads, as follows:

1. Living in such manner as to keep up our health foundations.

2. Living in such manner as to form and keep a desirable number of health-giving habits.

3. Living in such manner as to correct or overcome any defects or weaknesses that may already exist.

These aims will need some further explanation.

Our Health Foundations. — By these are meant the conditions within the body that enable it to care for the

cells in a proper manner. For example, to keep the cells where they belong and give them needed room, the body must have its natural shape. Correct shape, then, is one of our health foundations. Motion, which all the cells must have, is provided through the muscles. If the muscles get weak, the movements of the body and through the body are not sufficient for the needs of the cells. Good

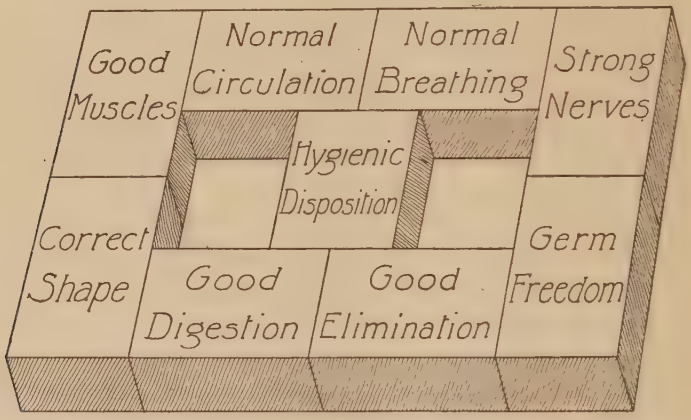

FIG. 7. — **Our Health Foundations.** A figurative representation of conditions within the body that are necessary to the welfare of the cells.

muscles, then, are also a health foundation. Food to get to the cells must first be digested, and this can only be done properly when all the digestive processes go on as they should. Good digestion is likewise a health foundation.

Other health foundations are: a normal circulation of the blood, normal breathing, good elimination of waste, strong nerves, an hygienic disposition, and freedom from germs. Speaking figuratively, our "temple of health" is supported by our health foundations (Fig. 7).

How our Methods of Living Affect our Health Foundations. — That our methods of living have decided effects upon the conditions that enable the body to care properly for the cells, is easily seen when we study the results of what we do in the everyday routine of living. How we sit and how we stand affects our bodily shape. How we work and exercise affects our muscles. What we eat and how we eat it affects our digestion. How we dress affects our shape, our breathing, and the circulation of blood to different parts. How we sleep and how we work affects our nerves. And the way people treat us and we treat them affects our disposition. From these and other examples we may infer that right living builds up our health foundations, while wrong living weakens them.

Right Living and our Habits. — Habits are modes of action which have been acquired by repetition. They cause us to live in certain ways and to do different things that affect our health, work, and happiness, and without much thought on our part as to what we are doing or why we are doing it. Habits that affect the health may be counted as good when they aid in keeping up our health foundations. They are bad to the extent that they cause them to be injured. Since right living causes constant repetition of acts that are beneficial, it builds up habits that cause us to go on living as we should. Living wrongly, for the same reason, binds us to forms of activity and methods of treating the body that tend to make us go on injuring ourselves. On this account, any general scheme of right living must include efforts for the formation of habits that are beneficial, and the breaking of habits that are detrimental.

Right Living and Health Repairing. — No matter how well we live, we are apt to have weaknesses and defects,

and at times to get injured. This is in the nature of things and is the result often of causes outside of ourselves. Whether we are to blame for our weaknesses and defects or not, we must not permit them to remain any longer than can be helped. Man is much like an automobile in the results that follow something's being wrong. Like the punctured tire, the broken spring, or the defective steering wheel, it will, if neglected, nearly always lead to something worse. He must, therefore, do for himself what he would do for his car. He must correct, or have corrected, the thing which is wrong just as soon as this can be done.

The School Physical Examination. — The purpose of this is to enable the pupil to discover any weaknesses that he may have in order that he may correct them as soon as possible.[1] While some of these may require medical aid for their relief, most of them are of such a nature that the pupil can himself, through corrective hygiene, bring about improvements. Some of the things that members of the physiology class may need to correct for themselves are the following:

Weak muscles.

Body out of its natural shape.

Troubles of the feet — corns, bunions, ingrown nails, and weak arches.

Cold hands and feet from too little blood flowing into them.

Indigestion and constipation.

Nervousness, headache, and worrying.

A badly kept mouth.

A faulty disposition.

Health-destroying habits — eating between meals, sitting and standing in bad positions, drinking coffee and tea, smoking, etc.

[1] See author's *Principles of Health Control*, pp. 40–43.

These are all the result of wrong living. Correcting them will improve both the health and the methods of living.

Summary. — Right living is the kind of living that aids the body in the different ways by which it cares for the cells. Wrong living interferes in one way or another with the body plan of providing for the cells. We are living rightly when we are keeping up our health foundations, making and keeping all necessary health-giving habits, and are diligent in correcting anything about the body that may be wrong.

Exercises. — 1. Define good health and poor health from the standpoint of the cells.

2. Name the different things which the body does for the cells in order to keep them healthy and active.

3. How does right living help the body in helping the cells? How does wrong living hinder?

4. What do we mean by our health foundations? Name them.

5. Compare effects of right and wrong living upon our health foundations.

6. Define a habit. What have habits to do with our living rightly or wrongly?

7. Why cannot one with bad habits live rightly? What is the remedy?

8. Why must anything wrong about the body be corrected at the earliest moment? Illustrate.

CHAPTER V

THE BLOOD

Two liquids of similar nature are found in the body, known as the blood and the lymph. These are closely related in function and together they form the nutrient fluid referred to in the preceding chapter. The blood is the more familiar of the two liquids, and the one which can best be considered at this time.

The Blood: where Found. — The blood occupies and moves through a system of closed tubes, known as the blood vessels. By means of these vessels the blood is made to circulate through all parts of the body, but from them it does not escape under normal conditions. Though provisions exist whereby liquid materials may both enter and leave the blood stream, it is only when the blood vessels are cut or broken that the blood, as blood, is able to escape from its inclosures.

Physical Properties of the Blood. — Experiments such as those described at the close of this chapter reveal the more important physical properties of the blood. It may be shown to be heavier and denser than water; to have a faint odor and a slightly salty taste; to have a bright red color when it contains oxygen and a dark red color when oxygen is absent; and to undergo, when exposed to certain conditions, a change called coagulation. These properties are all accounted for through the different materials that enter into the formation of the blood.

Composition of the Blood. — To the naked eye the blood appears as a thick but simple liquid; but when examined with a compound microscope, it is seen to be complex in nature, consisting of at least two distinct portions. One of these is a clear, transparent liquid; while the other is made up of many small, round bodies that float in the liquid. The liquid portion of the blood is called the *plasma;* the small bodies are known as *corpuscles.* Two varieties of

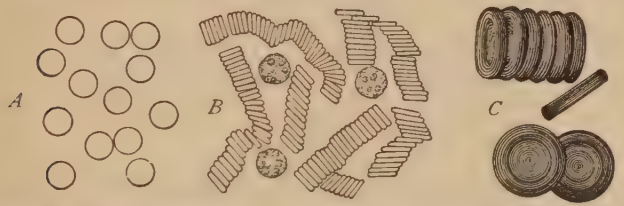

FIG. 8. — **Blood corpuscles**, highly magnified. *A.* Red corpuscles as they appear in diluted blood. *B.* Arrangement of red corpuscles in rows between which are white corpuscles, as may be seen in undiluted blood. *C.* Red corpuscles much enlarged to show the form.

corpuscles are described — the *red* corpuscles and the *white* corpuscles (Fig. 8). Other round particles, smaller than the corpuscles, may also be seen under favorable conditions. These latter are known as *blood platelets.*

Red Corpuscles. — The red corpuscles are classed as cells, although, as found in the blood of man and the other mammals (Fig. 9), they have no nuclei.[1] Each one consists of a little mass of protoplasm, called the *stroma,* which contains a substance having a red color, known as *hemoglobin.* The shape of the red corpuscle is that of a circular disk with concave sides. It has a width of about $\frac{1}{3200}$ of an inch (7.9 microns[2]) and a thickness of

[1] In birds, reptiles, amphibians, and fishes the red corpuscles have nuclei (Fig. 9).

[2] The micron is the unit of microscopical measurements. It is equal to $\frac{1}{1000}$ of a millimeter and is indicated by the symbol μ.

about $\frac{1}{13000}$ of an inch (1.9 microns). The red corpuscles are exceedingly numerous, there being as many as five millions in a small drop (one cubic millimeter) of healthy

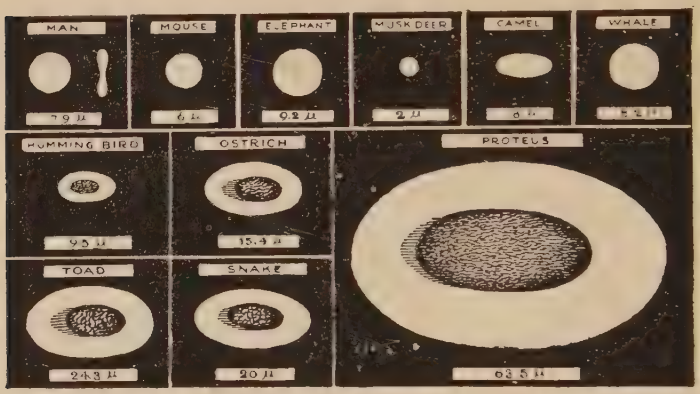

FIG. 9. — **Red corpuscles from various animals.** Those from mammals are without nuclei, while those from birds and cold-blooded animals have nuclei.

blood. But the number varies somewhat and is greatly diminished during certain forms of disease.

It is the *function* of the red corpuscles to serve as *oxygen carriers* for the cells. They take up oxygen at the lungs and release it at the cells in the different tissues.[1] The performance of this function depends upon the hemoglobin.

Hemoglobin. — This substance has the remarkable property of forming, under certain conditions, a weak chemical union with oxygen and, when the conditions are reversed, of separating from it. It forms

[1] The peculiar shape of the red corpuscle has no doubt some relation to its work. Its circular form is of advantage in getting through the small blood vessels, while its extreme thinness brings all of its contents very near the surface — a condition which aids the hemoglobin in taking up oxygen. If the corpuscles were spherical in shape, some of the hemoglobin could not, on account of the distance from the surface, so readily unite with the oxygen.

about nine tenths of the solid matter of the red corpuscles and to it is due the colors of the blood. When united with the oxygen it forms a compound, called *oxyhemoglobin*, which has a bright red color; the hemoglobin alone has a dark red color. These colors are the same as those of the blood as it takes on and gives off oxygen. The stroma, which forms only about one tenth of the solid matter of the corpuscles, serves as a contrivance for holding the hemoglobin. The conditions which cause the hemoglobin to unite with oxygen in the lungs and to separate from it in the tissues, will be considered later (Chapter X).

Disappearance and Origin of Red Corpuscles. — The red corpuscles, being cells without nuclei, are necessarily short-lived. It has been estimated that during a period of one to two months, all the red corpuscles in the body at a given time will have disappeared and their places taken by new ones. The origin of new corpuscles, however, and the manner of ridding the blood of old ones are problems that are not as yet fully solved. The removal of the products of broken down corpuscles is supposed to take place both in the liver and in the spleen.[1]

Regarding the origin of the red corpuscles, the evidence now seems conclusive that large numbers of them are formed in the red marrow of the bones. The red marrow is located in what is known as the spongy substance of the bones (Chapter XIX) and consists, to a large extent, of cells somewhat like the red corpuscles, but differing from them in having nuclei. These appear to be constantly in a state of reproduction. The blood, flowing through the minute cavities containing these cells, carries those that have been loosened out into the blood stream. Nuclei appear in the red corpuscles at the time of their formation, but these quickly separate and, according to some authorities, form the blood platelets.

White Corpuscles. — The white corpuscles, or *leucocytes*, are cells of a general spherical shape, each containing one, two, or more nuclei. They are much less numerous than the red, there being on the average only one white cor-

[1] The coloring matter of the bile consists of compounds formed by the breaking down of the hemoglobin; the spleen contains many large cells that seem to have the power first of "engulfing" and later of decomposing red corpuscles. A further evidence that the spleen aids in the removal of worn-out corpuscles is found in the fact that during diseases that cause a destruction of the red corpuscles, such as the different forms of malaria, the spleen becomes enlarged.

puscle to about every five hundred of the red ones. On the other hand, the white corpuscles are larger than the red, one of the former being equal in volume to about three of the latter.

The white corpuscles are found, when studied under favorable conditions, to possess the power of changing their shape and, by this means, of moving from place to

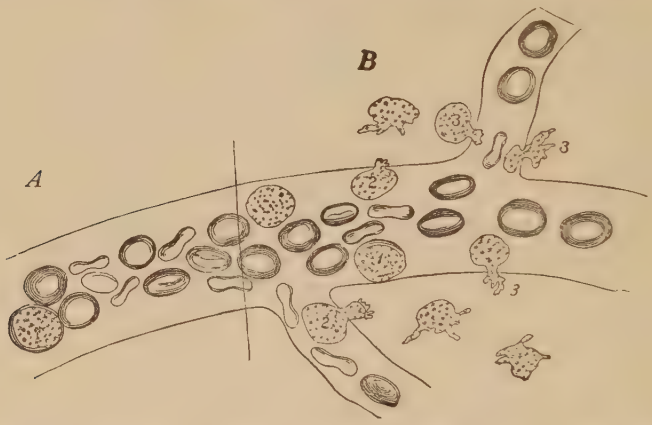

FIG. 10. — **Escape of white corpuscles from a small blood vessel** (Hall). At *A* the conditions are normal, but at *B* some excitation in the surrounding tissue leads to a migration of corpuscles. 1, 2, and 3 show different stages of the passage.

place. This property enables them to penetrate the walls of capillaries and to pass with the lymph in between the cells of the tissues. The white corpuscles are, therefore, not confined to the blood vessels, as are the red corpuscles, but migrate through the intercellular spaces (Fig. 10). If any part of the body becomes inflamed, the white corpuscles collect there in large numbers; and, on breaking down, they form most of the white portion of the sore, called the *pus*.

New white corpuscles are formed from old ones, by cell-division. Their production may occur in almost any part of the body, but usually takes place in the lymphatic glands (Chapter VII) and in the spleen, where conditions for their development are especially favorable. In these places they are found in great abundance and in various stages of development.

Functions of White Corpuscles. — The main use of the white corpuscles appears to be that of a destroyer of disease germs. These consist of minute organisms that find their way into the body and, by living upon the tissues and fluids and by depositing toxins (poisons) in them, cause different forms of disease. Besides destroying germs that may be present in the blood, the white corpuscles also leave the blood and attack germs that have invaded the cells. By forming a kind of wall around any foreign substance, such as a splinter, that has penetrated the skin, they are able to prevent the spread of germs through the body. In a similar manner they also prevent the germs from boils, abscesses, and sore places in general from getting to and infecting other parts of the body.[1] Another function ascribed to the white corpuscles is that of aiding in the coagulation of the blood (page 33); and still another, of aiding in the healing of wounds.

Plasma. — The plasma is a complex liquid, being made up of water and of substances dissolved in the water. The dissolved substances consist mainly of foods for the cells and wastes from the cells.

1. *The foods* represent the same classes of materials as are taken in the daily fare, *i.e.*, proteins, carbohydrates,

[1] An infected part of the body, such as a boil or abscess, should never be bruised or squeezed until the time of opening. Pressure tends to break down the wall of white corpuscles and to spread the infection. Pus from a sore contains germs and should not, on this account, come in contact with any part of the skin. (See treatment of skin wounds, Chapter XXIII.)

fats, and salts (Chapter XII). Three kinds of proteins are found in the plasma, called *serum albumin*, *serum globulin*, and *fibrinogen*. These resemble, in a general way, the white of raw egg, but differ from each other in the readiness with which they coagulate. Fibrinogen coagulates more readily than the others and is the only one that changes in the ordinary coagulation of the blood. The others remain dissolved during this process, but are coagulated by chemical agents and by heat. While all of the proteins probably serve as food for the cells, the fibrinogen, in addition, is a necessary factor in the coagulation of the blood (page 33).

The only representative of the carbohydrates in the plasma is *dextrose*. This is a variety of sugar, being derived from starch and the different sugars that are eaten. The *fat* in the plasma is in minute quantities and appears as fine droplets — the form in which it is found in milk. While several mineral salts are present in small quantities in the plasma, *sodium chloride*, or common salt, is the only one found in any considerable amount. The mineral salts serve various purposes, one of which is to cause the proteins to dissolve in the plasma.

2. *The wastes* are formed at the cells, whence they are passed by the lymph into the blood plasma. They are carried by the blood until removed by the organs of excretion. The two waste products found in greatest abundance in the plasma are carbon dioxid and urea.

The substances dissolved in the plasma form about 10 per cent of the whole amount. The remaining 90 per cent is water. Practically all the constituents of the plasma, except the wastes, enter the blood from the digestive organs.

Purposes of Water in the Blood. — Not only is water the

most abundant constituent of the blood; it is, in some respects, the most important. It is the liquefying portion of the blood, holding in solution the constituents of the plasma and floating the corpuscles. Deprived of its water, the blood becomes a solid substance. Through the movements of the blood the water also serves the purpose of a transporting agent in the body. The cells in all parts of the body require water and this is supplied to them from the blood. Water is present in the corpuscles as well as in the plasma and forms about 80 per cent of the entire volume of the blood.

Coagulation of the Blood. — If the blood is exposed to some unnatural condition, such as occurs when it escapes from the blood vessels, it undergoes a peculiar change known as *coagulation*.[1] In this change the corpuscles are collected into a solid mass, known as the *clot*, thereby separating from a liquid called the *serum*. The serum, which is similar in appearance to the blood plasma, differs from that liquid in one important respect as explained below.

Causes of Coagulation. — Although coagulation affects all parts of the blood, only one of its constituents is found in reality to coagulate. This is the fibrinogen. The formation of the clot and the separation of the serum is due almost entirely to the action of this substance. Fibrinogen is for this reason called the *coagulable constituent of the blood*. In the plasma the fibrinogen is in a liquid form; but during coagulation it changes into a white, stringy solid, called *fibrin*. This appears in the clot and is the cause of its formation. Forming as a network of exceed-

[1] Coagulation is not confined to the blood. The white of an egg coagulates when heated and when acted upon by certain chemicals, and the clabbering of milk also is a coagulation.

ingly fine and very delicate threads (Fig. 11) *throughout the mass of blood* that is coagulating, the fibrin first entangles the corpuscles and then, by contracting, draws them into the solid mass or clot.[1] The contracting of the fibrin also squeezes out the serum. This liquid contains all the constituents of the plasma except the fibrinogen.

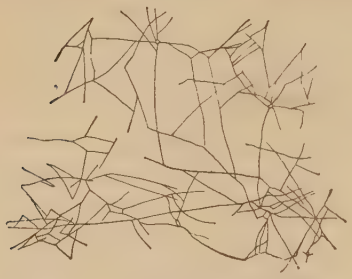

FIG. 11. — **Fibrin threads** (after Ranvier). These by contracting draw the corpuscles together and form the clot.

Fibrin Ferment and Calcium. — Most difficult of all to answer have been the questions: What causes the blood to coagulate outside of the blood vessels and what prevents its coagulation inside of these vessels? The best explanation offered as yet upon this point is as follows: Fibrinogen does not of itself change into fibrin, but is made to undergo this change by the presence of another substance, called *fibrin ferment*. This substance is not a regular constituent of the blood, but is formed as occasion requires. It is supposed to result from the breaking down of the white corpuscles, and perhaps also from the blood platelets, when the blood is exposed to unnatural conditions. The formation of the ferment leads in turn to the changing of the fibrinogen into fibrin.

Another substance which is necessary to the process of coagulation is the element calcium. If compounds of calcium are absent from the blood, coagulation does not take place. These are, however, regular constituents of healthy blood. Whether the presence of the calcium is necessary to the formation of the ferment or to the action of the ferment upon the fibrinogen is unknown.

Purpose of Coagulation. — The purpose of coagulation is to check the flow of blood from wounds. The fact that the blood is contained in and kept flowing continuously

[1] If the blood be stirred or "whipped" while it is coagulating, the clot may be broken up and the fibrin separated as fast as it forms. The blood which then remains consists of serum and corpuscles and will not coagulate. It is known as "defibrinated" blood.

through a system of *connected* vessels causes it to escape rapidly from the body whenever openings in these vessels are made. Clots form at such openings and close them up, stopping in this way the flow that would otherwise go on indefinitely. Coagulation, however, does not stop the flow of blood from the large vessels. From these the blood runs with too great force for the clot to form within the wound.

Time Required for Coagulation. — The rate at which coagulation takes place varies greatly under different conditions. It is influenced strongly by temperature; heat hastens and cold retards the process. It may be prevented entirely by lowering the temperature of the blood to near the freezing point. The presence of a foreign substance increases the rapidity of coagulation, and it has been observed that bleeding from small wounds is more quickly checked by covering them with linen or cotton fibers. The fibers in this case hasten the process of coagulation.

Quantity of Blood. — The quantity of blood is estimated to be about one thirteenth of the entire weight of the body. This for the average individual is an amount weighing nearly twelve pounds and having a volume of nearly one and one half gallons. About 46 per cent by volume of this amount is made up of corpuscles and 54 per cent of plasma. Of the plasma about 10 per cent consists of solids and 90 per cent of water, as already stated.

Functions of the Blood. — The blood is the great carrying, or distributing, agent in the body. Through its movements (considered in the next chapter) it carries food and oxygen to the cells and waste materials from the cells Much of the blood may, therefore, be regarded as *freight* in the process of transportation. The blood also carries, or distributes, heat. Taking up heat in the warm parts of the body, it gives it off at places having a lower temperature. This enables all parts of the body to keep at about the same temperature.

In addition to serving as a carrier, the blood has antiseptic properties, *i.e.*, it destroys disease germs. While

this function is mainly due to the white corpuscles, it is due in part to the plasma.[1] Through its coagulation, the blood also closes leaks in the small blood vessels. The blood is thus seen to be a liquid of several functions.

Changes in the Blood. — In performing its functions in the body the blood must of necessity undergo rapid and continuous change. The red corpuscles, whose changes have already been noted, appear to be the most enduring constituents of the blood. The plasma is the portion that changes most rapidly. Yet in spite of these changes the quantity and character of the blood remain practically constant.[2] This is because there is a *balancing* of the forces that bring about the changes. The addition of various materials to the blood just equals the withdrawal of the same materials from the blood. Somewhat as a vessel of water (Fig. 12) having an inflow and an outflow which are equal in amount may keep always at the same level, the balancing of the intake and outgo of the blood keeps its composition about the same from time to time.

FIG. 12. — **A balanced change** in water. The level remains constant although the water is continually changing; suggestive of the changes in the blood.

Right Living and the Blood. — What the blood accomplishes as a carrier must depend to a large extent upon what it carries. It may carry things detrimental to the

[1] Certain substances, called *opsonins*, have recently been shown to exist in the plasma, that aid the white corpuscles in their work of destroying germs. The opsonins appear to act in such a manner as to weaken the germs and make them more susceptible to the attacks of the white corpuscles.

[2] Some of the changes in the blood are very closely related to our everyday habits and inclinations. For example, a lack of nourishment in the blood causes hunger and this leads to the taking of food. If the fluids of the body become too dense, a feeling of thirst is aroused which prompts one to drink water.

cells as well as those that are beneficial. It may carry germs and germ poisons, harmful drugs, and an excess of waste and too little oxygen, and when it does, there will be injury to the cells. To prevent such injury we must, in the ordinary routine of living,

Keep the blood as free as possible from germs and germ poisons.

Keep up the quality and the number of the red corpuscles.

Attend to matters that affect the purity of the blood.

To Keep the Blood Free from Germs and Germ Poisons. — This is entirely too big a problem to be fully considered at this time, for in most any kind of germ attack, the blood is to some extent involved. (See Chapter XXX.) We can, however, note the two main ways by which germs get into the blood. These are as follows:

1. By sore places, called *infections*, in which the germs rapidly increase and from which they enter the blood. To permit diseased tonsils, abscesses at the roots of teeth, and sores on the skin to go on uncured, is a sure way of keeping germs and germ poisons in the blood.

2. By permitting ourselves to be bitten by blood-sucking insects, such as mosquitoes. The germs that cause malaria, yellow fever, and other diseases get into the blood in this way.

Health and Beauty through the Red Corpuscles. — Since good health depends upon plenty of oxygen at the cells, it must also depend upon having a sufficient number of oxygen carriers in the blood — the red corpuscles. But another interesting use of the red corpuscles is to give color to the skin — to supply the coveted reddish tint to the complexion. Blood rich in red corpuscles is Nature's own beautifier. One who is lacking in red corpuscles is pale in color and is said to be *anemic*.

To Have a Good Supply of Red Corpuscles. — The red corpuscles are short lived. To keep well supplied, new ones have to be put back into the blood as fast as the old ones wear out and disappear. While this is done successfully as long as we keep ourselves in good health, there are certain things that should be looked after. These are:

1. *Our food.* We should eat a balanced diet (p. 132) and include in this foods rich in iron, such as egg yolks, lean meat, spinach, prunes, raisins, and asparagus. The hemoglobin of the red corpuscles is a compound of iron.

2. *Plenty of outdoor life and exercise and sufficient sleep.*

3. *Avoidance of malaria and other diseases that injure the red corpuscles* (p. 404).

4. *Avoidance of carbon monoxid gas.*

Some of these require further consideration.

Outdoor Life and the Red Corpuscles. — A Russian hygienist made blood counts of nineteen boys and eighteen girls before a two months' summer outing and again after their return. With the boys the red corpuscles had increased on the average from 3,884,000 per cubic millimeter to 4,480,000, and with the girls from 3,760,000 to 4,488,000 per cubic millimeter. There was also a marked increase in the amount of hemoglobin in the corpuscles. This investigation showed the great importance to the blood of life out of doors. Every boy and girl should be out of doors as much as possible. *Remember your red corpuscles!*

Carbon Monoxid and the Red Corpuscles. — Carbon monoxid (CO) is a colorless gas which is formed when the carbon in fuels burns incompletely, as shown by its forming smoke. When it burns completely, the carbon unites with all the oxygen that it can to form carbon dioxid (CO_2), which is harmless in small amounts. When we breathe air containing carbon monoxid, it unites with the hemoglobin

of the red corpuscles to make an almost permanent compound, called *carbon monoxid-hemoglobin*. This destroys the ability of the red corpuscles to carry oxygen and is a frequent cause of death. We are in danger from carbon monoxid gas under the following circumstances:

1. By being in a room into which the products of combustion are escaping, as from a gas stove which has no connecting pipe with the outside. This danger increases as the flame smokes.

2. By being in an inclosed space, as a garage, which is receiving the exhaust from a car. On this account, the car should always be warmed up in the open.[1]

3. By being in a room in which illuminating gas is escaping from broken pipes or an open cock. Carbon monoxid is a constituent of most fuel and lighting gases.

One becoming unconscious either from carbon monoxid or carbon dioxid should have artificial respiration applied at once (p. 118).

How the Blood is Kept Pure. — This is done by avoiding overeating and by keeping all the organs that throw off waste active. Especially must there be a free movement of the bowels each day.

Summary. — The blood is the carrying or transporting agent of the body. It consists in part of constituents, such as the red corpuscles, that enable it to carry different substances, and in part of the materials that are being carried. The latter, which include food and oxygen for the cells and wastes from the cells, may be classed as freight. Certain constituents in the blood destroy disease germs,

[1] A five-passenger car has been found to produce 35 cubic feet of carbon monoxid gas per hour in a garage when running idle and 65 cubic feet per hour when racing. This is much more than enough to cause death in a short time in such a small enclosed space.

and other constituents, by coagulating, close small leaks in the blood vessels. Although subject to rapid and continuous change, the blood is able — by reason of the balancing of materials added to and withdrawn from it — to remain about the same in quantity and composition.

Exercises. — 1. Compare blood and water with reference to weight, density, color, odor, and complexity of composition.

2. Show by an outline the different constituents of the blood.

3. Compare the red and white corpuscles with reference to size, shape, number, origin, and function.

4. Name some use or purpose for each constituent of the blood.

5. What constituents of the blood may be regarded as freight and what as agents for carrying this freight?

6. After coagulation, what portions of the blood are found in the clot? What portions are found in the serum?

7. What purposes are served by water in the blood?

8. Show how the blood, though constantly changing, is kept about the same in quantity, density, and composition.

9. In the lungs the blood changes from a dark to a bright red color and in the tissues it changes back to dark red. What is the cause of these changes?

10. If the oxygen and hemoglobin formed a strong instead of a weak chemical union, could the hemoglobin then act as an oxygen carrier? Why?

11. How are we to keep the blood free from germs?

12. What habits of living favor the development of red corpuscles?

13. How does carbon monoxid injure the blood and cause death? Discuss sources of danger from this gas.

14. How does keeping skin clean aid in keeping the blood pure?

PRACTICAL WORK

To Examine the Red Corpuscles. — Blood for this purpose is easily obtained from the finger. With a handkerchief, wrap one of the fingers of the left hand from the knuckle down to the first joint. Bend this joint and give it a sharp prick with the point of a sterilized needle just above the root of the nail. Pressure applied to the under

side of the finger will force plenty of blood through a very small opening. (To prevent any possibility of blood poisoning the needle should be sterilized. This may be done by dipping it in alcohol or by holding it for an instant in a hot flame. It is well also to wash the finger with soap and water, or with alcohol, before the operation.) Place a small drop of the blood in the middle of a glass slide, protect the same with a cover glass, and examine with a compound microscope. At least two specimens should be examined, one of which should be diluted with a little saliva or a physiological salt solution.[1] In the diluted specimen the red corpuscles appear as amber-colored, circular, disk-shaped bodies. In the undiluted specimen they show a decided tendency to arrange themselves in rows, resembling rows of coins. (Singly, the corpuscles do not appear red when highly magnified.)

A few white corpuscles may generally be found among the red ones in the undiluted specimen. These become separated by the formation of the red corpuscles into rows. They are easily recognized by their larger size and by their silvery appearance, due to the light shining through them.

To Examine White Corpuscles. — Obtain from the butcher a small piece of the neck sweetbread of a calf. Press it between the fingers to squeeze out a whitish, semi-liquid substance. Dilute with physiological salt solution on a glass slide and examine with a compound microscope. Numerous white corpuscles of different kinds and sizes will be found. Make sketches.

To Prepare Models of Red Corpuscles. — Several models of red corpuscles should be prepared for the use of the class. Clay and putty may be pressed into the form of red corpuscles and allowed to harden, and small models may be cut out of blackboard crayon. Excellent models can be molded from plaster of Paris as follows: Coat the inside of the lid of a baking-powder can with oil or vaseline and fill it even full of a thick mixture of plaster of Paris and water. After the plaster has set, remove it from the lid and with a pocket-knife round off the edges and hollow out the sides until the general form of the corpuscle is obtained. The models may be colored red if it is desired to match the color as well as the form of the corpuscle.

[1] A physiological salt solution is prepared by dissolving .6 of a gram of common salt in 100 cc. of distilled water or pure cistern water. This solution, having the same density as the plasma of the blood, does not act injuriously upon the corpuscles.

CHAPTER VI

THE CIRCULATION

A CARRIER must move. To enable the blood to carry food and oxygen *to* the cells and waste materials *from* the cells, and also to distribute heat, it is necessary to keep it moving, or circulating, in all parts of the body. So closely related to the welfare of the body is the circulation[1] of the blood, that its stoppage for only a brief interval of time results in death.

Discovery of the Circulation. — The discovery of the circulation of the blood was made about 1616 by an English physician named Harvey. In 1619 he announced it in his public lectures and in 1628 he published a treatise in Latin on the circulation. The chief arguments advanced in support of his views were the presence of valves in the heart and veins, the continuous movement of the blood in the same direction through the blood vessels, and the fact that the blood comes from a cut artery in jets, or spurts, that correspond to the contractions of the heart.

No other single discovery with reference to the human body has proved of such great importance. A knowledge of the nature and purpose of the circulation was the necessary first step in understanding the plan of the body and the method of maintaining life, and physiology as a science dates from the time of Harvey's discovery.

Organs of Circulation. — The organs of circulation, or blood vessels, are of four kinds, named the heart, the arteries, the capillaries, and the veins. They serve as con-

[1] The term "circulation" literally means moving in a circle. While the blood does not move through the body in a circle, the term is justified by the fact that the blood flows out continually from a single point, the heart, and to this point is continually returning.

trivances both for holding the blood and for keeping it in motion through the body. The heart, which is the chief organ for propelling the blood, acts as a force pump, while the arteries and veins serve as tubes for conveying the blood from place to place. Moreover, the blood vessels are so connected that the blood moves through them in a regular order, performing two well-defined circuits.

The Heart. — The human heart, roughly speaking, is about the size of the clenched fist of the individual owner. It is situated very near the center of the thoracic cavity and is almost completely surrounded by the lungs. It is cone-shaped and is so suspended that the small end hangs downward, forward, and a little to the left. When from excitement, or other cause, one becomes conscious of the movements of the heart, these appear to be in the left portion of the chest, a fact which accounts for the erroneous impression that the heart is on the left side. The position of the heart in the cavity of the chest is shown in Fig. 13.

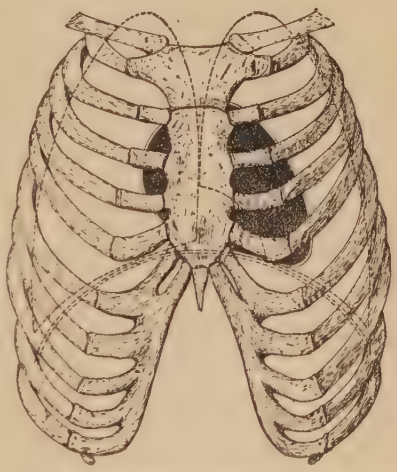

FIG. 13. — **Heart in position** in thoracic cavity. Dotted lines show position of diaphragm and of margins of lungs.

The Pericardium. — Surrounding the heart is a protective covering, called the pericardium. This consists of a closed membranous sac so arranged as to form a double covering around the heart. The heart does not lie inside

of the pericardial sac, as seems at first glance to be the case, but its relation to this space is like that of the hand to the inside of an empty sack which is laid around it (Fig. 14). The inner layer of the pericardium is closely attached to the heart muscle, forming for it an outside covering. The outer layer hangs loosely around the heart and is continuous with the inner layer at the top. The outer layer also connects at certain places with the membranes surrounding the lungs and is attached below to the diaphragm. Between the two layers of the pericardium is secreted a liquid which prevents friction from the movements of the heart.

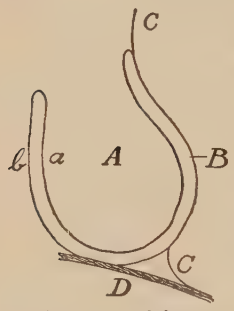

FIG. 14. — **Diagram of section of the pericardial sac,** heart removed. *A*. Place occupied by the heart. *B*. Space inside of pericardial sac. *a*. Inner layer of pericardium and outer lining of heart. *b*. Outer layer of pericardium. *C*. Covering of lung. *D*. Diaphragm.

Cavities of the Heart. — The heart is a hollow, muscular organ which has its interior divided by partitions into four distinct cavities. The main partition extends from top to bottom and divides the heart into two similar portions, named from their positions the right side and the left side. On each side are two cavities, the one being directly above the other. The upper cavities are called *auricles* and the lower ones *ventricles*. To distinguish these cavities further, they are named from their positions the right auricle and the left auricle, and the right ventricle and the left ventricle (Fig. 15). The auricles on each side communicate with the ventricles below; but after birth there is no communication between the cavities on the opposite sides of the heart. All the cavities of the heart are lined with a smooth, delicate membrane, called the *endocardium*.

Valves of the Heart. — Located at suitable places in the heart are four gate-like contrivances, called valves. The purpose of these is *to give the blood a definite direction* in its movements. They consist of tough, inelastic sheets of connective tissue, and are so placed that pressure on one side causes them to come together and shut up the passageway, while pressure on the opposite side causes them to open. A valve is found at the opening of each auricle into the ventricle, and at the opening of each ventricle into the artery with which it is connected.

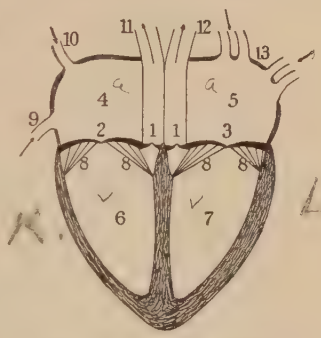

FIG. 15. — **Diagram showing plan of the heart.** 1. Semilunar valves. 2. Tricuspid valve. 3. Mitral valve. 4. Right auricle. 5. Left auricle. 6. Right ventricle. 7. Left ventricle. 8. Chordæ tendineæ. 9. Inferior vena cava. 10. Superior vena cava. 11. Pulmonary artery. 12. Aorta. 13. Pulmonary veins.

The valve between the right auricle and the right ventricle is called the *tricuspid* valve. It is suspended from a thin ring of connective tissue which surrounds the opening, and its free margins extend into the ventricle (Fig. 16). It consists of three parts, as its name implies, which are thrown together in closing the opening. Joined to the free edges of this valve are many small, tendinous cords which connect at their lower ends with muscular pillars in the walls of the ventricle. These are known as the *chordæ tendineæ*, or heart tendons. Their purpose is to serve as *valve stops*, to prevent the valve from being thrown, by the force of the blood stream, back into the auricle.

The *mitral*, or bicuspid, valve is suspended around the opening between the left auricle and the left ventricle,

with the free margins extending into the ventricle. It is exactly similar in structure and arrangement to the tricuspid valve, except that it is stronger and is composed of two parts instead of three.

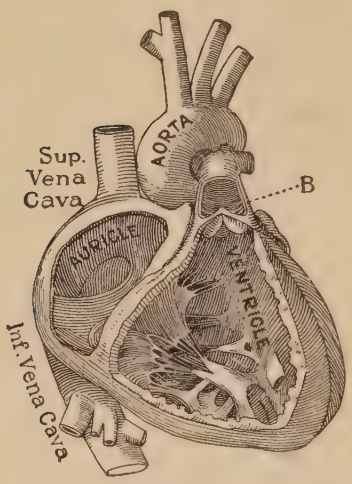

FIG. 16. — **Right side of heart** dissected to show cavities and valves. *B*. Right semilunar valve. The tricuspid valve and the chordæ tendineæ shown in the ventricle.

The *right semilunar* valve is situated around the opening of the right ventricle into the pulmonary artery. It consists of three pocket-shaped strips of connective tissue which hang loosely from the walls when there is no pressure from above; but upon receiving pressure, the pockets fill and project into the opening, closing it completely (Fig. 16). The *left semilunar* valve is around the opening of the left ventricle into the aorta, and is similar in all respects to the right semilunar valve.

Differences in the Parts of the Heart. — Marked differences are found in the walls surrounding the different cavities of the heart. The walls of the ventricles are much thicker and stronger than those of the auricles, while the walls of the left ventricle are two or three times thicker than those of the right. A less marked but similar difference exists between the auricles and also between the valves on the two sides of the heart. These differences in structure are all accounted for by the work done by the different portions of the heart. The greater the work, the heavier the structures that perform the work.

Connection with Arteries and Veins. — Though the heart is in communication with all parts of the circulatory system, it makes actual connection with only a few of the blood tubes. These enter the heart at its upper portion (Fig. 15), but connect with its different cavities as follows:

1. *With the right auricle*, the superior and the inferior venæ cavæ and the coronary veins. The superior vena cava receives blood from the head and the upper extremities; the inferior vena cava, from the trunk and the lower extremities; and the coronary veins, from the heart itself.

2. *With the left auricle*, the four pulmonary veins. These receive blood from the lungs and empty it into the left auricle.

3. *With the right ventricle*, the pulmonary artery. This receives blood from the heart and by its branches distributes it to all parts of the lungs.

4. *With the left ventricle*, the aorta. The aorta receives blood from the heart and through its branches delivers it to all parts of the body.

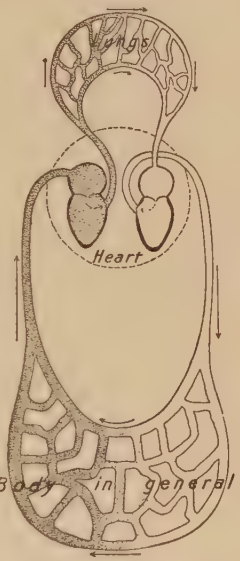

FIG. 17. — **Diagram of the circulation,** showing in general the work done by each part of the heart. The right ventricle forces the blood through the lungs and into the left auricle. The left ventricle forces blood through all parts of the body and back to the right auricle. The auricles force blood into the ventricles.

How the Heart does its Work. — The heart is a muscular pump[1] and does its work through the contracting and

[1] The heart at first glance seems to bear little resemblance to the pumps in common use. When it is remembered, however, that any contrivance which

relaxing of its walls. During contraction the cavities are closed and the blood is forced out of them. During relaxation the cavities open and are refilled. The valves direct the flow of the blood, being so arranged as to keep it moving always in the same direction (Fig. 17).

The heart, however, is not a single or a simple pump, but consists in reality of *four* pumps which correspond to its different cavities. These connect with each other and with the blood vessels over the body in such a manner that each aids in the general movement of the blood.

Work of Auricles and Ventricles Compared. — In the work of the heart the two auricles contract at the same time — their contraction being followed immediately by the contraction of both ventricles. After the contraction of the ventricles comes a period of rest, or relaxation, about equal in time to the period of contraction of both the auricles and the ventricles.[1] On account of the work which they perform, the auricles have been called the "feed pumps" of the heart; and the ventricles, the "force pumps."[2] It is the function of the auricles to collect the blood from the veins, to let this run slowly into the ventricles when both the

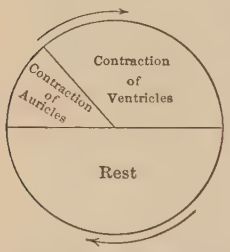

FIG. 18. — Diagram illustrating the "cardiac cycle."

moves a fluid by varying the size of a cavity is a pump, it is seen that not only the heart, but the chest in breathing and also the mouth in sucking a liquid through a tube, are pumps in principle. The ordinary syringe bulb illustrates the class of pumps to which the heart belongs. (See Practical Work.)

[1] The contraction of the heart is known as the *systole* and its relaxation as the *diastole*. The systole plus the diastole forms the so-called "cardiac cycle" (Fig. 18). This consists of (1) the contraction of the auricles, (2) the contraction of the ventricles, and (3) the period of rest. The heart systole includes the contraction of both the auricles and the ventricles.

[2] Martin, *The Human Body*.

auricles and ventricles are relaxed, and finally, by contracting, *to force an excess of blood into the ventricles*, thereby distending their walls. The ventricles, having in this way been fully charged by the auricles, now contract and force their contents into the large arteries.

Sounds of the Heart. — Two distinct sounds are given out by the heart as it pumps the blood. One of them is a dull and rather heavy sound, while the other is a short, sharp sound. The short sound follows quickly after the dull sound and the two are fairly imitated by the words "lŭbb, dŭp." While the cause of the first sound is not fully understood, most authorities believe it to be due to the contraction of the heart muscle and the sudden tension on the valve flaps. The second sound is due to the closing of the semilunar valves. These sounds are easily heard by placing an ear against the chest wall. They are of great value to the physician in determining the condition of the heart.

Arteries and Veins. — These form two systems of tubes which reach from the heart to all parts of the body. The arteries receive blood from the heart and distribute it to the capillaries. The veins receive the blood from the capillaries and return it to the heart. The arteries and veins are similar in structure, both having the form of tubes and both having three distinct layers, or coats, in their walls. The corresponding coats in the arteries and veins are made up of similar materials, as follows:

1. *The inner coat* consists of a delicate lining of flat cells resting upon a thin layer of connective tissue. The inner coat is continuous with the lining of the heart and provides a smooth surface over which the blood glides with little friction.

2. *The middle coat* consists mainly of non-striated, or involuntary, muscular fibers. This coat is quite thin in the veins, but in the arteries it is rather thick and strong.

3. *The outer coat* is made up of a variety of connective

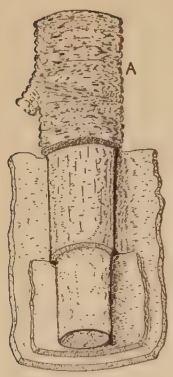

FIG. 19. — **Artery** dissected to show the coats.

tissue and is also much thicker and stronger in the arteries than in the veins.

Marked differences exist between the arteries and the veins, and these vessels are readily distinguished from each other. The walls of the arteries are much thicker and heavier than those of the veins (Fig. 19). As a result these tubes stand open when empty, whereas the veins collapse. The arteries also are highly elastic, while the veins are but slightly elastic. On the other hand, many of the veins contain valves, formed by folds in the inner coat (Fig. 20), while the arteries have no valves. The blood flows more rapidly through the arteries than through the veins, the difference being due to the fact that the system of veins has a greater capacity than the system of arteries.

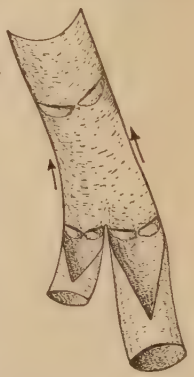

FIG. 20. — **Vein** split open to show the valves.

Why the Arteries are Elastic. — The elasticity of the arteries serves a twofold purpose. It keeps the arteries from bursting when the blood is forced into them from the ventricles, and it is a means of *supplying pressure to the blood while the ventricles are in a condition of relaxation.* The latter purpose is accomplished as follows:

Contraction of the ventricles fills the arteries overfull, causing them to swell out and make room for the excess of blood. Then while the ventricles are resting and filling, the stretched arteries press upon the blood to keep it

flowing into the capillaries. In this way *they cause the intermittent flow from the heart to become a steady stream in the capillaries.*

The swelling of the arteries at each contraction of the ventricle is easily felt at certain places in the body, such as the wrist. This expansion, known as the "pulse," is the chief means employed by the physician in determining the force and rapidity of the heart's action.

Purpose of the Valves in the Veins. — The valves in the veins are not used for directing the *general* flow of the blood, the valves of the heart being sufficient for this purpose. Their presence is necessary because of the pressure to which the veins are subjected in different parts of the body. The contraction of a muscle will, for example, close the small veins in its vicinity and diminish the capacity of the larger ones. The natural tendency of such pressure is to empty the veins in two directions — one in the same direction as the regular movement of the blood, but the other in the opposite direction. The valves by closing cause the contracting muscle to push the blood in one direction only — toward the heart. The valves in the veins are, therefore, an economical device for *enabling variable pressure* in different parts of the body *to assist in the circulation.* Veins like the inferior vena cava and the veins of the brain, which are not compressed by movements of the body, do not have valves.

Purposes of the Muscular Coat. — The muscular coat, which is thicker in the arteries than in the veins and is more marked in small arteries than in large ones, serves two important purposes. In the first place it, together with the elastic tissue, keeps the capacity of the blood vessels *equal to the volume of the blood.* Since the blood vessels are capable of holding more blood than may be

present at a given time in the body, there is a liability of empty spaces occurring in these tubes. Such spaces would seriously interfere with the circulation, since the heart pressure could not then reach all parts of the blood stream. This is prevented by the contracted state, or "tone," of the blood vessels, due to the muscular coat.

In the second place, the muscular coat serves the purpose of *regulating* the amount of blood which any given organ or part of the body receives. This it does by varying the caliber of the arteries going to the organ in question. To increase the blood supply, the muscular coat relaxes. The arteries are then dilated by the blood pressure from within so as to let through a larger quantity of blood. To diminish the supply, the muscle contracts, making the caliber of the arteries less, so that less blood can flow to this part of the body. Since the need of organs for blood varies with their activity, the muscular coat serves in this way a very necessary purpose.

Capillaries. — The capillaries consist of a network of minute blood vessels which connect the terminations of the smallest arteries with the beginnings of the smallest veins (Fig. 21). They have an average diameter of less than one two-thousandth of an inch (12 μ) and an average length of less than one twenty-fifth of an inch (1 millimeter). Their walls consist of a single

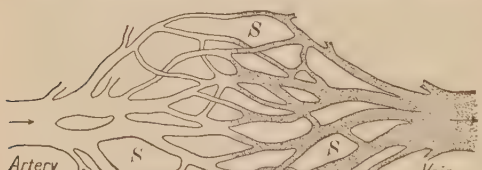

FIG. 21. — **Diagram of network of capillaries** between a very small artery and a very small vein. Shading indicates the change of color of the blood as it passes through the capillaries. *S*. Places between capillaries occupied by the cells.

coat which is continuous with the lining of the arteries and veins. This coat is formed of a single layer of thin, flat cells placed edge to edge (Fig. 22). With a few exceptions, the capillaries are found in great abundance in all parts of the body.

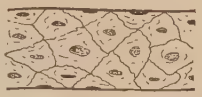

FIG. 22. — **Surface of capillary** highly magnified, showing its coat of thin cells placed edge to edge.

Functions of the Capillaries. — On account of the thinness of their walls, the capillaries are able to serve a two-fold purpose in the body:

1. They admit materials into the blood vessels.

2. They allow materials to pass from the blood vessels to the surrounding tissues.

When it is remembered that the blood, as blood, does not escape from the blood vessels under normal conditions, the importance of the work of the capillaries is apparent. To serve its purpose as a carrier, there must be places where the blood can load up with the materials which it is to carry, and places also where these can be unloaded. Such places are supplied by the capillaries.

The capillaries also serve the purpose of spreading the blood out and of bringing it very near the individual cells in all parts of the body (Fig. 21).

Functions of Arteries and Veins. — While the capillaries provide the means whereby materials may both enter and leave the blood, the arteries and veins serve the general purpose of passing the blood from one set of capillaries to another. Since pressure is necessary for moving the blood, these tubes must connect with the source of the pressure, which is the heart. In the arteries and veins the blood neither receives nor gives up material, but having received or given up material at one set of capillaries, it is then pushed through these tubes to where it can serve a similar purpose in another set of capillaries (Fig. 23).

Divisions of the Circulation. — Man, in common with all warm-blooded animals, has a double circulation, a fact

which explains the double structure of his heart. The two divisions are known as the *pulmonary* and the *systemic* circulations. By the former the blood passes from the right ventricle through the lungs, and is then returned to the left auricle; by the latter it passes from the left ventricle through all parts of the body, returning to the right auricle.

The general plan of the circulation is indicated in Fig. 23. All the blood flows continuously through both circulations and passes the various parts in the following order: right auricle, tricuspid valve, right ventricle, right semilunar valve, pulmonary artery and its branches, capillaries of the lungs, pulmonary veins, left auricle, mitral valve, left ventricle, left semilunar valve, aorta and its branches, systemic capillaries, the smaller veins, superior and inferior venæ cavæ, and then again into the right auricle.

In the pulmonary capillaries the blood gives up carbon dioxid and receives oxygen, changing from a dark red to a bright red color. In the systemic capillaries it gives up oxygen, receives carbon dioxid and other impurities, and changes back to a dark red color.

In addition to the two main divisions of the circulation, special circuits are found in various places. Such a circuit in the liver is called the *portal* circulation, and another in the kidneys is termed the *renal* circulation. To some extent the blood supply to the walls of the heart is also outside of the general movement; it is called the *coronary* circulation.

Blood Pressure and Velocity. — The blood, in obedience to physical laws, passes continuously through the blood vessels, moving always from a place of greater to one of less pressure. Through the contraction of the ventricles, a relatively high pressure is maintained in the arteries nearest the heart.[1] This pressure diminishes rapidly in the

[1] The pressure maintained by the left ventricle has been estimated to be nearly three and one half pounds to the square inch — a pressure sufficient to sustain a column of water eight feet high. The pressure maintained by the right ventricle is

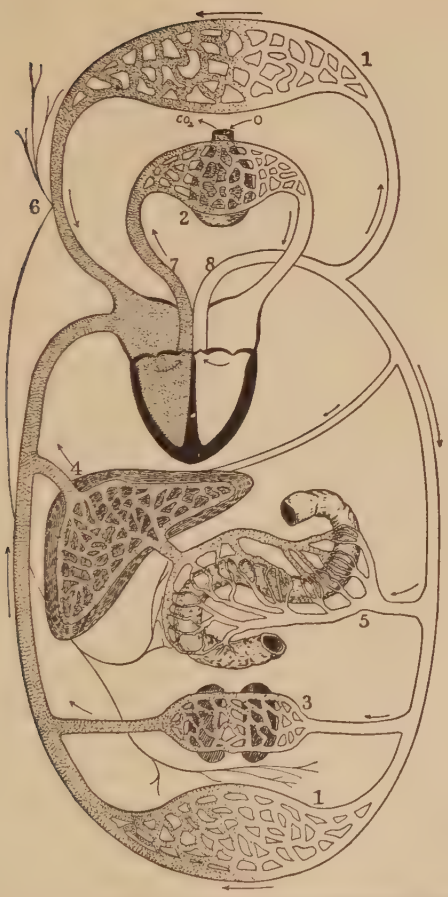

FIG. 23. — **General scheme of the circulation,** showing places where the blood takes on and gives off materials. 1. Body in general. 2. Lungs. 3. Kidneys. 4. Liver. 5. Organs of digestion. 6. Lymph ducts. 7. Pulmonary artery. 8. Aorta.

small arteries, becomes comparatively slight in the capillaries, and falls practically to nothing in the veins. Near the heart in the superior and inferior venæ cavæ, the pressure at intervals is said to be *negative*. This means that the blood from these veins is actually drawn into the right auricle by the expansion of the chest walls in breathing.[1]

The velocity of the blood is greatest in the arteries, less in the veins, and *much* less in the capillaries than in either the arteries or the veins. The slower flow of the blood through the capillaries is accounted for by the fact that their united area is many times greater than that of the arteries which supply, or the veins which relieve, them. This allows the same quantity of blood, flowing through them in a given time, a wider channel and causes it to move more slowly. The time required for a complete circulation is less than one minute.

Summary of Causes of Circulation. — The chief factor in the circulation of the blood is, of course, the heart. The ventricles keep a pressure on the blood which is sufficient to force it through all the blood tubes and back to the auricles. The heart is aided in its work by the elasticity of the arteries, which keeps the blood under pressure while the ventricles are in a state of relaxation. It is also aided by the muscles and elastic tissue in all of the blood vessels. These, by keeping the blood vessels in a state of "tone," or so contracted that their capacity just equals the volume of the blood, enable pressure from the heart to be transmitted to all parts of the blood stream. A further aid to the circulation is found in the valves in the veins, which enable muscular contraction within the body, and variable pressure upon its surface, to drive the blood toward the heart. The heart is also aided to some extent by the movements of the chest walls in breathing. The organs of circulation are under the control of the nervous system (Chapter XXV).

about one third as great. In maintaining this pressure the heart does a work equal to about one two-hundredth of a horse power.

[1] The location of the heart in the thoracic cavity causes movements of the chest walls to draw blood into the right auricle for the same reason that they "draw" air into the lungs.

Summary. — The blood, to serve as a transporting agent, must be kept continually moving through all parts of the body. The blood vessels hold the blood, supply the channels and force necessary for its circulation, and provide conditions which enable materials both to enter and to leave the blood stream. The heart is the chief factor in propelling the blood, although the muscles and the elastic tissue in the walls of the arteries and the valves in the veins are necessary aids in the process. In the capillaries the blood takes on and gives off materials, while the arteries and veins serve chiefly as tubes for conveying the blood from one system of capillaries to another.

Exercises. — 1. Of what special value in the study of the body was the discovery of the circulation of the blood?

2. State the necessity for a circulating liquid in the body.

3. Show by a drawing the general plan of the heart, locating and naming the essential parts. Show also the connection of the large blood vessels with the cavities of the heart.

4. Compare the purpose served by *chordæ tendineæ* to that served by doorstops (the strips that the door strikes in closing).

5. Explain how the heart propels the blood. What special work is performed by each of its divisions?

6. Define a valve. Of what use are the valves in the heart? In the veins?

7. By what means is pressure from contracting muscles in different parts of the body made to assist in the circulation?

8. Of what advantage is the elasticity of the arteries?

9. How is blood forced from the capillaries back to the heart?

10. Why should there be a difference in structure between the two sides of the heart?

11. Following Fig. 23, trace the blood through a complete circulation, naming all the divisions in the order of the flow of the blood.

12. If the period of rest following the period of contraction of the heart be as long as the period of contraction, how many hours is the heart able to rest out of every twenty-four?

13. State the functions of the capillaries. Show how their structure adapts them to their work.

PRACTICAL WORK

In showing the relations of the different parts of the heart, a large dissectible model is of great service (Fig. 24). Indeed, where the time of the class is limited, the practical work may be confined to the study of the heart model, diagrams of the heart and the circulation, and a few simple experiments. However, where the course is more extended, the dissection of the heart of some animal as described below is strongly advised.

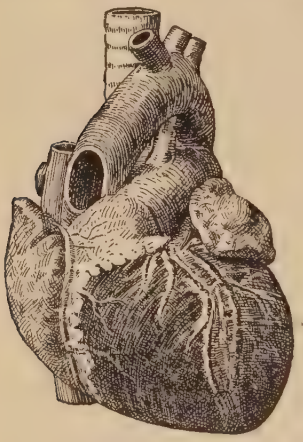

FIG. 24. — **Model** for demonstrating the heart.

Observations on the Heart. Procure, by the assistance of the butcher, the heart of a sheep, calf, or hog. To insure the specimen against mutilation, the lungs and the diaphragm must be left attached to the heart. In studying the different parts, good results will be obtained by observing the following order:

1. Observe the connection of the heart to the lungs, diaphragm, and large blood vessels. Inflate the lungs and observe the position of the heart with reference to them.

2. Examine the sac surrounding the heart, called the *pericardium*. Pierce its lower portion and collect the pericardial fluid. Increase the opening thus made until it is large enough to slip the heart out through it. Then slide back the pericardium until its connection with the large blood vessels above the heart is found. Observe that a thin layer of it continues down from this attachment, forming the outer covering of the heart.

3. Trace out for a short distance and study the veins and arteries connected with the heart. The arteries are to be distinguished by their thick walls. The heart may now be severed from the lungs by cutting the large blood vessels, care being taken to leave a considerable length of each one attached to the heart.

4. Observe the outside of the heart. The thick, lower portions contain the cavities called *ventricles*; the thin, upper, ear-shaped portions are the *auricles*. The thicker and denser side lies toward the left of the animal's body and is called the *left* side of the heart; the other is the

right side. Locate the right auricle and the right ventricle; the left auricle and the left ventricle.

5. Lay the heart on the table with the front side up and the apex pointing from the operator. This places the left side of the heart to his left and the right side to his right. Notice the groove between the ventricles, called the inter-ventricular groove. Make an incision half an inch to the right of this groove and cut towards the base of the heart until the pulmonary artery is laid open. Then, following within half an inch of the groove, cut down and around the right side of the heart. The wall of the right ventricle may now be raised and the cavity exposed. Observe the extent of the cavity, its shape, its lining, its columns of muscles, its half columns of muscles, its tendons (*chordæ tendineæ*), the tricuspid valve from the under side, etc. Also notice the valve at the beginning of the pulmonary artery (the right semilunar) and the sinuses, or depressions, in the artery immediately behind its divisions.

6. Now cut through the middle of the loosened ventricular wall from the apex to the middle of the right auricle, laying it open for observation. Observe the openings into the auricle, there being one each for the *vena cava superior*, the *vena cava inferior*, and the coronary vein. Compare the walls, lining, shape, size, etc., with the ventricle below.

7. Cut off the end of the left ventricle about an inch above the apex. This will show the extension of the cavity to the apex; it will also show the thickness of the walls and the shape of the cavity. Split up the ventricular wall far enough to examine the mitral valve and the *chordæ tendineæ* from the lower side.

8. Make an incision in the left auricle. Examine its inner surface and find the places of entrance of the pulmonary veins. Examine the mitral valve from above. Compare the two sides of the heart, part for part.

9. Separate the aorta from the other blood vessels and cut it entirely free from the heart, care being taken to leave enough of the heart attached to the artery to insure the semilunar valve's being left in good condition. After tying or plugging up the holes in the sides of the artery, pour water into the small end and observe the closing of the semilunar valve. Repeat the experiment until the action of the valve is understood. Sketch the artery, showing the valve in a closed condition.

To illustrate the Action of a Ventricle. — Procure a syringe bulb with an opening at each end. Connect a rubber tube with each opening.

letting the tubes reach into two tumblers containing water. By alternately compressing and releasing the bulb, water is pumped from one vessel into the other. The bulb may be taken to represent one of the ventricles. What action of the ventricle is represented by compressing the bulb? By releasing the pressure? Show by a sectional drawing the arrangement of the valves in the syringe bulb.

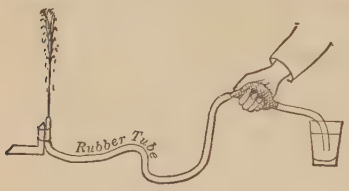

FIG. 25. — **Illustrating elasticity of arteries.**

To show the Advantage of the Elasticity of Arteries. — Connect the syringe bulb used in the last experiment with a rubber tube three or four feet in length and having rather thin walls. In the opposite end of the rubber tube insert a short glass tube which has been drawn (by heating) to a fine point (Fig. 25). Pump water into the rubber tube, observing:

1. The swelling of the tube (pulse) as the water is forced into it. (This is best observed by placing the fingers on the tube.)

2. The forcing of water from the pointed tube during the interval when no pressure is being applied from the bulb. Compare with the action of the arteries when blood is forced into them from the ventricles.

Repeat the experiment, using a long glass tube terminating in a point instead of the rubber tube. (In fitting the glass tube to the bulb use a very short rubber tube.) Observe and account for the differences in the flow of water through the inelastic tube.

FIG. 26. — **Simple apparatus** for showing advantage of valves in veins.

To show the Advantage of Valves in the Veins. — Attach an open glass tube one foot in length to each end of the rubber tube used in the preceding experiment and fill with water (by sucking) to within about six inches of the end. Lay on the table with the glass tubes secured in an upright position (Fig. 26). Now compress the tube with the hand, noting that the water rises in both tubes, being pushed in both directions. This effect is similar to that produced on the blood when a vein having no valves is compressed.

Now imitate the action of a valve by clamping the tube at one point, or by closing it by pressure from the finger, and then compressing with

the hand some portion of the tube on the table. Observe in this instance that the water is all pushed in the same direction. The movement of the water is now like the effect produced on the blood in veins having valves when the veins are compressed.

To show the Position of the Valves in the Veins. — Exercise the arm and hand for a moment to increase the blood supply. Expose the forearm and examine the veins on the surface. With a finger, stroke one of the veins toward the heart, noting that, as the blood is pushed along one side of the finger the blood follows on the other side. Now stroke the vein toward the hand. Places are found beyond which the blood does not follow the finger. These mark the positions of valves.

To study the Circulation in a Frog's Foot (Optional). — A compound microscope is needed in this study and for extended examination it is best to destroy the frog's brain. This is done by inserting some blunt-pointed instrument into the skull cavity from the neck and moving it about. A small frog, on account of the thinness of its webs, gives the best results. It should be attached to a thin board which has an opening in one end over which the web of the foot may be stretched. Threads should extend from two of the toes to pins driven into the board to secure the necessary tension of the web, and the foot and lower leg should be kept moist. Using a two-thirds-inch objective, observe the branching of the small arteries into the capillaries and the union of the capillaries to form the small veins. The appearance is truly wonderful, but allowance must be made for the fact that the *motion* of the blood is magnified, as well as the different structures, and that it appears to move much faster than it really does. With a still higher power, the movements of the corpuscles through the capillaries may be studied.

NOTE. — To perform this experiment without destroying the brain, the frog is first carefully wrapped with strips of wet cloth and securely tied to the board. The wrapping, while preventing movements of the frog, must not interfere with the circulation.

CHAPTER VII

THE LYMPH AND ITS MOVEMENT THROUGH THE BODY

The blood, it will be remembered, moves everywhere through the body in a system of *closed* tubes. These keep it from coming in contact with any of the cells of the body except those lining the tubes themselves. The capillaries, to be sure, bring the blood very near the cells of the different tissues; still, there is need of a liquid to fill the space between the capillaries and the cells and to transfer materials from one to the other. The lymph occupies this position and does this work. The position of the lymph with reference to the capillaries and the cells is shown in Fig. 27.

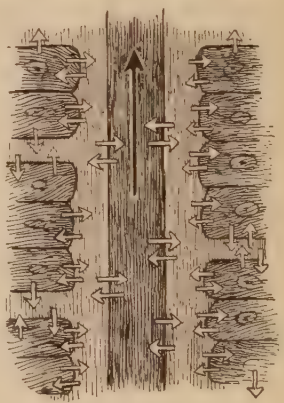

Fig. 27. — **Diagram showing position of the lymph** with reference to the blood and the cells. The central tube is a capillary. The arrows indicate the direction of slight movements in the lymph.

Origin of the Lymph. — The chief source of the lymph is the plasma of the blood. As before described, the walls of the capillaries consist of a single layer of flat cells placed edge to edge. Partly on account of the pressure upon the blood and partly on account of the natural tendency of liquids to pass through animal membranes, a considerable portion of the plasma penetrates the thin walls and enters the spaces occupied by the lymph.

The cells themselves also help to form the lymph, since the water and wastes leaving the cells add to its bulk. These mix with the plasma from the blood, forming the resultant liquid which is the lymph. A considerable amount of the material absorbed from the food canal also enters the lymph tubes, but this passes into the blood before reaching the cells.

Composition and Physical Properties of the Lymph.[1] — As would naturally be expected, the composition of the lymph is similar to that of the blood. In fact, nearly all the important constituents of the blood are found in the lymph, but in different proportions. Food materials for the cells are present in smaller amounts than in the blood, while impurities from the cells are in larger amounts. As a rule the red corpuscles are absent from the lymph, but the white corpuscles are present and in about the same numbers as in the blood.

The physical properties of the lymph are also similar to those of the blood. Like the blood, the lymph is denser than water and also coagulates, but it coagulates more slowly than does the blood. The most noticeable difference between these liquids is that of color, the lymph being colorless. This is due to the absence of red corpuscles. The quantity of lymph is estimated to be considerably greater than that of the blood.

Lymph Vessels. — Most of the lymph lies in minute cavities surrounding the cells and in close relations with the capillaries (Figs. 27 and 30). These are called *lymph spaces*. Connecting with the lymph spaces on the one

[1] On account of its position in the body, the lymph is not easily collected for examination. Still, nearly every one will recall some experience that has enabled him to see lymph. The liquid in a water blister is lymph, and so also is the liquid which oozes from the skin when it is scraped or slightly scratched. Swelling in any part of the body is due to the accumulation of lymph at that place.

hand, and with certain blood vessels on the other, is a system of tubes that return the lymph to the blood stream. The smallest of these, and the ones in greatest abundance, are called *lymphatics*. They consist of slender, thin-walled tubes, which resemble veins in structure, and, like the veins, have valves. They differ from veins, however, in being more uniform in size and in having thinner walls.

The lymphatics in different places gradually converge toward, and empty into, the two main lymph tubes of the body. The smaller of these tubes, called the *right lymphatic duct*, receives the lymph from the lymphatics in the right arm, the right side of the head, and the region of the right shoulder. It connects with, and empties its contents into, the right subclavian vein at the place where it is joined by the right jugular vein (Fig. 28).

The larger of the lymph tubes is called the *thoracic duct*. This receives lymph from all parts of the body

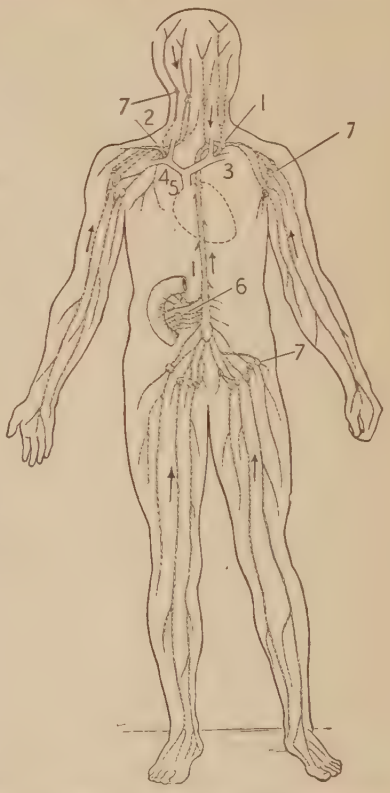

FIG. 28. — **Diagram of drainage system for the lymph.** 1. Thoracic duct. 2. Right lymphatic duct. 3. Left subclavian vein. 4. Right subclavian vein. 5. Superior vena cava. 6. Lacteals. 7. Lymphatic glands. The small tubes connecting with the lymph spaces in all parts of the body are the lymphatics.

not drained by the right lymphatic duct, and empties it into the left subclavian vein. Connection is made with the subclavian vein on the upper side at the place where it is joined by the left jugular vein. The thoracic duct has a length of from sixteen to eighteen inches, and is about as large around as a goose quill. The lower end terminates in an enlargement in the abdominal cavity, called the *receptacle of the chyle*. It is provided with valves throughout its course, in addition to one of considerable size which guards the opening into the blood vessel.

The lymphatics which join the thoracic duct from the small intestine are called the *lacteals* (Fig. 28). These do not differ in structure from the lymphatics in other parts of the body, but they perform a special work in absorbing the digested fat (Chapter XVI).

Lymphatic Glands. — The lymphatic glands, sometimes called lymph nodes, are small and somewhat rounded bodies situated along the course of the lymphatic tubes. They vary in size, some of them being an inch or more in length. The lymph vessels generally open into them on one side and leave them on the other (Figs. 28 and 30). They are not glands in function, but are so called because of their having the general form of glands. They provide favorable conditions for the development of white corpuscles (page 31). They also separate harmful germs and poisonous wastes from the lymph, thereby preventing their entrance into the blood.

Relations of the Lymph, the Blood, and the Cells. — While the blood is necessary as a carrying, or transporting, agent in the body, the lymph is necessary for transferring materials from the blood to the cells and *vice versa*. Serving as a physiological "go between," or medium of exchange, the lymph enables the blood to minister to the

needs of the cells. But the lymph and the blood, everything considered, can hardly be looked upon as two separate and distinct liquids. Not only do they supplement each other in their work and possess striking similarities, but each is made in its movements to pass into the vessels occupied by the other, so that they are constantly mixing and mingling. For these and other reasons, they are more properly regarded as two divisions of a single liquid — one which, by adapting itself to different purposes,[1] supplies all the conditions of a nutrient fluid for the cells.

Movements of the Lymph. — As compared with the blood, the lymph must be classed as a quiet liquid. But, as already suggested, it has certain movements which are necessary to the purposes which it serves. A careful study shows it to have three well-defined movements as follows:

1. A movement from the capillaries toward the cells.
2. A movement from the cells toward the capillaries.
3. A movement of the entire body of lymph from the lymph spaces into the lymphatics and along these channels to the ducts through which it enters the blood.

By the first movement the cells receive their nourishment. By the second and third movements the lymph, more or less laden with impurities, is returned to the blood stream. (See Figs. 28 and 30.)

Causes of the Lymph Movements. — Let us consider first the movement through the lymph tubes. No pump, like the heart, is known to be connected with these tubes and

[1] In certain small animals of the lowest types a single liquid, serving as a medium of exchange between the cells and the body surface, supplies all the needs of the organism. In larger animals, however, where materials have to be moved from one part of the cell group to another, a portion of the nutrient fluid is used for purposes of transportation. This is confined in channels where it is set in motion by suitable organs. The portion which remains outside of the channels then transfers material between the cells, on the one hand, and the moving liquid, on the other.

to supply the pressure necessary for moving the lymph. There are, however, several forces that indirectly aid in its flow. The most important of these are as follows:

1. *Blood Pressure at the Capillaries.* — The plasma which is forced through the capillary walls by pressure from the heart makes room for itself by pushing a portion of the lymph out of the lymph spaces. This in turn presses upon the lymph in the tubes which it enters. In this way pressure from the heart is transmitted to the lymph, forcing it to move.

2. *Variable Pressure on the Walls of the Lymph Vessels.* — Pressure exerted on the sides of the lymph tubes by contracting muscles tends to close them up and to push the lymph past the valves, which, by closing, prevent its return (Fig. 29). Pressure at the surface of the body, provided that it is variable, also forces the lymph along. The valves in the lymph vessels serve the same purpose as those in the veins.

FIG. 29. — **Diagram** to show how the muscles pump lymph. *A*. Relaxed muscle beside which is a lymphatic tube. *B*. Same muscle in state of contraction.

3. *The Inspiratory Force.* — When the thoracic cavity is enlarged in breathing, the unbalanced atmospheric pressure is exerted from all directions towards the thoracic space. This not only causes the air to flow into the lungs (Chapter IX), but also causes a movement of the blood and lymph in such of their tubes as enter this cavity. It will be noted that both of the large lymph ducts terminate where their contents may be influenced by the respiratory movements.

Where the Lymph enters the Blood. — The fact that the lymph is poured into the blood at but two places, and these very close to each

other, requires a word of explanation. As a matter of fact, it is impossible for the lymph to flow into blood vessels at most places on account of the blood pressure. This would force the blood into the lymph vessels, instead of allowing the lymph to enter the blood. The lymph can enter only at some place where the blood pressure is less than the pressure that moves the lymph. Such a place is found in the thoracic cavity. As already pointed out (page 56), the blood pressure in the veins entering this cavity becomes, with each expansion of the chest, negative, *i.e.*, less than the pressure of the atmosphere on the outside of the body. This, as we have seen, aids in the flow of the blood into the right auricle. It also aids in the passage of lymph into the blood vessels. The lymph is said to be "sucked in," which means that it is forced in by the unbalanced pressure of the atmosphere.[1] Some advantage is also gained by the lymph duct's entering the subclavian vein on the upper side and at its union with the jugular vein. Everything considered, it is found that the lymph flows into the blood vessels where it can be "drawn in" by the movements of breathing and where it meets with no opposition from the blood stream itself (Fig. 30).

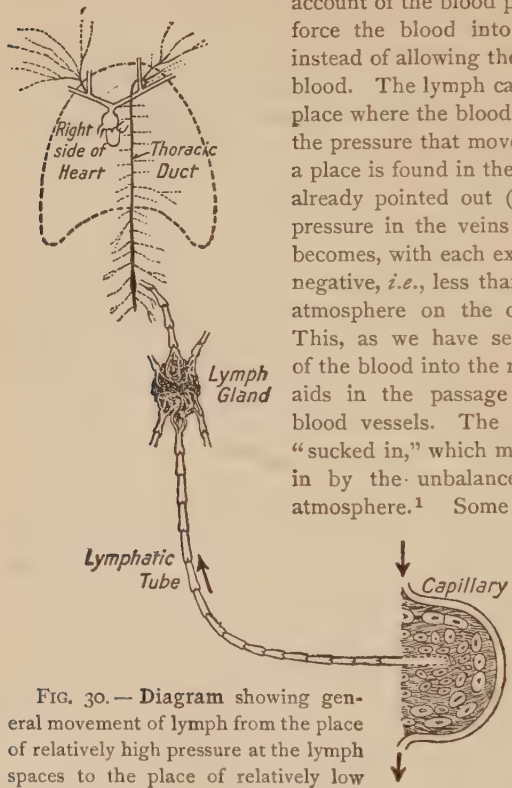

FIG. 30. — **Diagram** showing general movement of lymph from the place of relatively high pressure at the lymph spaces to the place of relatively low pressure in the thoracic cavity.

Lymph Movements at the Cells. — The double movement of the lymph from the capillaries toward the cells

[1] Surgeons in opening veins near the thoracic cavity have to be on their guard to prevent air from being sucked into them, thereby causing death.

and from the cells toward the capillaries is not entirely understood. Blood pressure in the capillaries undoubtedly has much to do in forcing the plasma through the capillary walls, but this tends to prevent the movement of the lymph in the opposite direction. Movements between the blood and the lymph are known to take place in part according to a general principle, called *osmosis*, which depends upon the movements of the tiny particles, or molecules, which make up these liquids.

Summary. — Between the cells and the capillaries is a liquid, known as the lymph, which is similar in composition and physical properties to the blood. It consists chiefly of escaped plasma. The vessels that contain it are connected with the system for the circulation of the blood. By adding new material to the lymph and withdrawing waste material from it, the blood keeps this liquid in a suitable condition for supplying the needs of the cells. The blood and the lymph together form the nutrient cell fluid of the body (p. 18).

Exercises. — 1. Explain the necessity for the lymph in the body. Just where is it found?

2. Compare lymph and water with reference to density, color, and complexity of composition.

3. Compare lymph and blood with reference to color, composition, and movement through the body.

4. Show how blood pressure in the capillaries causes a flow of the lymph.

5. Show how contracting muscles cause the lymph to move. Compare with the effect of muscles upon the blood in the veins.

6. Trace the lymph in its flow from the right hand to where it enters the blood; from the feet to where it enters the blood.

7. Show that the blood and the lymph together fulfill all the requirements of a nutrient cell fluid in the body.

CHAPTER VIII

HYGIENE OF THE CIRCULATION

To have our methods of living produce desirable effects upon the circulation, we must give attention to three kinds of causes — those that affect the heart, those that affect the resistance which has to be overcome by the blood in circulating, and those that influence the amount of blood flowing to different parts.

Disorders of the Heart. — The three following are by far the most frequent in occurrence:

1. *Leakage of the valves.* This is a condition in which the valves do not close up tight when the heart contracts. Instead of stopping the passage so that the heart's pressure will push all the blood forward, they let some of the blood leak back in the wrong direction (Fig. 31). This forces the heart to work harder to keep the blood flowing as fast as it should.

2. *Heart strain.* This is a condition in which the heart walls have become weak and stretched. Such walls cannot put enough pressure on the blood and sometimes the cavities themselves are not completely emptied.

3. *Functional troubles*[1]. These are conditions in which the heart fails to do its work in a proper manner when there is nothing wrong with its valves or its walls. The heart may beat too fast and skip beats and be irregular in other ways when its structures are sound in every respect.

[1] Heart disorders are of two kinds — organic and functional. Those that depend upon impaired structures — leaking valves, stretched walls, etc. — are said to be *organic*.

Causes of Heart Disorders. — The main cause for leakage of the valves is an attack of germs within the heart itself. The heart lining may become infected by germs carried by the blood to it from other places (p. 37), and when this happens, the valves may be so injured that they cannot close up tightly.

Heart strain is always the result of some kind of overwork of the heart. The heart can be overworked by strenuous exercise, especially when one is not used to it, and by conditions within the body that force it to work harder than it should.

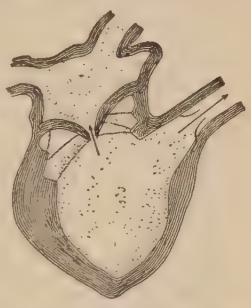

FIG. 31. — **Showing a leak** in the tricuspid valve.

There are two main causes for functional heart troubles: (1) an exhausted state of the nervous system, due to worry, overwork, eye strain, drugs,[1] and other causes; (2) the accumulation of gas in the stomach and intestines as a result of indigestion and of weak muscles in the walls of these organs (p. 148).

Methods of Protecting the Heart. — From the standpoint of the different causes of heart ailments, we have about five methods of protection:

1. *By avoiding infections* in any part of the body, such as the tonsils. This is the most important of the ways of protecting the heart valves.

2. *By avoiding overstrenuous exercise* when the heart is not prepared for it. One entering an athletic contest must prepare his heart for the ordeal by gradually increasing his exercise.

[1] *Tobacco heart* and *coffee heart* are names of functional heart troubles due to the drugs (nicotine and caffeine) in tobacco and coffee. Both are dangerous and both are avoided by avoiding the causes.

3. *By protecting the nervous system* and keeping up a good nervous reserve (Chapter XXVI). This is the most important way of avoiding functional troubles of the heart.

4. *By looking after the digestion* (Chapter XV) and keeping the muscles in walls of the stomach and intestines in good tone (p. 271).

5. *By keeping free from conditions that obstruct the flow of blood through the body* and which force the heart to work harder on this account. This method of protecting the heart needs further explanation.

Why the Blood Must Flow at a Given Speed. — It is a surprise to some to know how fast the blood flows around through the body (p. 56). It must flow as rapidly as it does in order to carry the oxygen to the cells as it is needed. Oxygen is not stored in the body, as food is stored, but is taken directly from the air. To get it rapidly enough from the lungs to the cells, the blood must move at a given rate, this increasing as we need more oxygen, as in the taking of exercise.

Should the blood be flowing too slowly to get the needed oxygen to the cells, nervous impulses (p. 329) are sent to the heart to make it work harder. When less is needed, the heart is made to beat slower. In this way the blood is kept flowing at just the right speed for delivering the oxygen.

Effect of Obstructions: How Overcome. — Any one pumping water through a tube having obstructions, knows that to get the same amount of water he must work harder than he would if these were not present. The heart, also, must work harder when there are obstructions in the blood vessels, to keep the blood flowing at the required speed. It contracts with greater force and this puts *more pressure* on the blood to push it along. While this keeps up the speed of the blood, it is very objectionable for two reasons:

1. It may overwork the heart and cause heart strain.

2. The high blood pressure may break some of the delicate blood vessels, such as those in the brain. Apoplexy usually results from this cause.

To avoid the harmful effects of keeping up a high blood pressure, we must *avoid obstructions in the circulation.*

Kinds of Circulatory Obstructions. — There are about five kinds of these obstructions, as follows:

1. *A keyed-up condition of the nerves.* This, by causing more contraction of the muscles in the walls of the blood vessels, makes it harder for the blood to flow through.

2. *Too much waste in the blood.* This keeps the blood from flowing freely through the blood vessels.

3. *The blood's being too dense.* This has about the same effect upon its flow as too much waste.

4. *Being too fat.* Excess of fat may cause pressure on the blood vessels to partly close them up.

5. *Disease of the blood vessels.* On account of attacks of germs, the walls of the blood vessels may become stiff and hard.

The general plan of avoiding obstructions to the circulation is that of avoiding the causes upon which they depend. This is largely a matter of right living.

Keep Down High Blood Pressure by Right Living. — To do this we must live rightly with reference to our nervous system, avoiding the keyed-up condition. We must live rightly as concerns the removal of waste from the body, avoiding constipation by all means. We must live rightly as concerns our eating. We must not overeat and we must avoid an excess of meat and excess of salt.[1] We must live

[1] On account of the waste that is in meat from the animal's body from which it is obtained, it adds to the waste in our bodies. We should never eat meat more than once a day, and better still, not more than two or three times a week. An excess of salt may get the blood too dense. We should put only enough salt on our food to satisfy the salt taste.

rightly with reference to our weight, holding in our appetite and exercising as may be necessary to keep from getting too fat. And then we must live in such manner as to avoid infections which, in turn, lead to infection of the heart and blood vessels.

These kinds of right living are of the greatest importance as we get older. High blood pressure is a common ailment in middle life and afterward. We must begin controlling it early.

Blood Should Flow in Right Amounts to all Parts. — If too little blood goes to any part of the body, the cells there fail to get as much of everything the blood carries as they need. They fail to get enough food, enough oxygen, and enough heat, and their waste is not carried away as fast as it should be. On this account, they are not as healthy and cannot do their work so well as they could were their needs fully supplied. Too little blood to the brain is a cause of fainting. On the other hand, the cells in places that get too much blood fare just as badly as those that get too little. In such places the movement is slow and sluggish and there is a crowding of blood and lymph into them. This causes swelling, weakness, and sometimes pain. On this account, a place getting an excess of blood is usually a place of low resistance to germs (p. 108).

Right Living and the Blood Flow to Different Parts. — Many things that we do in the ordinary routine of living have a marked effect upon the flow of blood to different parts. Exercise and warm clothing increase the flow of blood to the skin and diminish the flow to the inner linings of the body. Lack of exercise and clothing that is too thin do the opposite (Fig. 33). Walking, standing while at work, sleeping with the head higher than the feet, and wearing warm shoes and stockings all cause the blood to flow

more freely to the feet, while worry, strain of the eyes, and having the head hot, send the blood in larger amounts to the head (Fig. 32). We are living rightly as concerns the distribution of blood, when the general result is to have blood flow in right amounts to all parts of the body.

FIG. 32

FIG. 33

Probable distribution of blood when the hands and feet are cold (Fig. 32) and when the entire body is chilled (Fig. 33). Shaded portions indicate places of excess of blood.

How the Blood-Flow to any Part is Tested. — There are two simple ways of telling when any part of the body is getting enough blood. One of these is the temperature of the part. Since the blood is a carrier of heat, the part that is getting enough blood will be comfortably warm, or at least as warm as the average of other parts. Any part that is not getting enough blood will be cold. Cold hands and cold feet are good examples of this fact. If the skin

is not getting enough blood, there is a general feeling of chilliness.

The other test is that of color. On account of the red corpuscles, the blood gives a pinkish, or ruddy, color to the parts into which it flows freely. An excess of blood, on this account, causes the part to become "flushed" or "inflamed."

Why we Want Warm Hands, Warm Feet, and a Warm Skin. — We want them warm, for one thing, for comfort. Another advantage is that the good flow of blood that keeps them warm also keeps them built up. The warm skin, in addition, throws off more waste through the perspiration, or sweat. These, however, are not the main reasons. Having enough blood flowing into the hands and the feet prevents an excess flow to the brain (Fig. 32) and having a good skin circulation prevents an excess flow into the inner linings of the body — those of the nose, throat, lungs, stomach, and intestines (Fig. 33). This helps to avoid congestions in these linings and protects them from attacks of germs.

To Have a Good Flow of Blood to the Skin While Sleeping. — The standard arrangement for doing this is to sleep in a cold bedroom, but in a warm bed. Breathing the cold air all night long contracts the blood vessels in the linings of the nose, throat, and lungs, and so holds out of them an excess of blood. The warm skin, on the other hand, tends to expand the blood vessels at the surface so that they can receive more blood. On account of its effect upon the circulation, this method of sleeping is a great aid in the avoidance of colds and other diseases attacking the air passages, and also in sleeping soundly and in getting good elimination through the skin.

To Assist the one who Faints. — Since fainting is the result of too little blood flowing to the brain, we will

render the desired assistance by doing the things that aid in increasing the flow to that organ. To this end, tight clothing about the neck must be loosened and the patient put in a position in which the head is a little lower than the feet. Drops of cold water may be dashed on the face and smelling salts applied to the nose, as both stimulate the blood flow to the brain. If the fainting is prolonged, a physician should be called.

Alcohol and the Circulation. — Taken in any but small amounts, alcohol is a disturbing factor in the circulation. It increases the rate of the heart beat and dilates the capillaries. Its effect upon the capillaries is shown by the " bloodshot " eye and the " red nose " of the hard drinker. Another bad effect from the use of much alcohol is the weakening of the heart through the accumulation of fat around this organ and within the heart muscle. The use of alcohol also leads in many cases to a hardening of the walls of the arteries such as occurs in old age. Right living precludes the use of alcohol in any form.

To Check Flow of Blood from Wounds. — The flow from small wounds is easily checked by binding cotton or linen fiber over the place. The absorbent cotton, sold in small packages at drug stores, is excellent for this purpose and should be kept in every home. A simple method of checking " nosebleed " is that of drawing air through the bleeding nostril, while the other nostril is compressed with the finger. Another method is to insert a small roll of paper under upper lip, and another to apply cold to the back of the neck. Where the bleeding is persistent, both nostrils should be plugged with small rolls of clean cotton or paper. When this is done, the plugs should not be removed too soon because of danger of starting the flow afresh.

In dealing with large wounds the services of a physician

are indispensable. But in waiting for the physician to arrive temporary aid must be rendered. The one who gives such aid should first decide whether an artery or a vein has been injured. This is easily determined by the nature of the blood stream, which is in jets, or spurts, from an artery, but flows steadily from a vein. If an artery is injured, the limb should be tightly bandaged on the side of the wound nearest the heart; if a vein, on the side farthest from the heart. In addition to this, the edges of the wound should be closed and covered with cotton fiber and the limb should be placed on a support above the level of the rest of the body. A large handkerchief makes a convenient bandage if properly applied. This should be folded diagonally and a knot tied in the middle. Opposite ends are then tied, making a loose-fitting loop around the limb. The knot is placed directly over the blood vessel to be compressed and a short stick inserted in the loop. The necessary pressure is then applied by twisting the handkerchief with the stick. Time must not be lost, however, in the preparation of a suitable bandage. The blood vessel should be compressed with the fingers while the bandage is being prepared.

Summary. — We have in the normal circulation of the blood one of our main foundations of health (p. 22). To maintain this foundation we must supply conditions that keep the blood healthy, that protect the heart and blood vessels, that shield the nervous system and aid the digestion, that keep the circulation free from obstructions, and that keep the blood flowing in right amounts to all parts. The kinds of right living that do these things will aid in keeping up all of our health foundations.

Exercises. — 1. How does keeping the entire body free from infection safeguard the heart and the blood vessels?

2. Discuss the nature, causes, and methods of preventing heart strain.

3. How do functional heart troubles differ from those that are organic? State main causes of the functional troubles.

4. How does getting enough sleep protect the heart? How do proper habits of eating do the same thing?

5. Why must the blood flow at a given speed through the body? How is the speed kept up when there are obstructions to the circulation?

6. State the causes for and objections to a high blood pressure.

7. What kinds of right living aid in keeping down a high blood pressure? Explain.

8. What harm results from too little blood flowing to any part of body? From too much?

9. Name several causes in everyday life that affect the amount of blood flowing to different parts.

10. Why should we have a good flow of blood to the hands and feet? To the skin? How can we tell when we are getting this?

11. Discuss methods of getting a good blood flow to the feet. To the skin.

12. State advantages to the circulation of sleeping in a warm bed in a cold bedroom.

13. How may we help one who faints?

14. How do we check the flow of blood from small wounds? From large ones?

15. Write a short essay on the subject, "How we keep up our Health Foundation of Normal Circulation."

CHAPTER IX

RESPIRATION

Through the movements of the blood and the lymph, materials entering the body are transported to the cells, and wastes formed at the cells are carried to the organs which remove them from the body. We are now to consider the passage of materials from outside the body to the cells and *vice versa*. One substance which the body constantly needs is oxygen, and one which it is constantly throwing off is carbon dioxid. Both of these are constituents of

The Atmosphere. — The atmosphere, or air, completely surrounds the earth as a kind of envelope, and comes in contact with everything upon its surface. It is composed chiefly of oxygen and nitrogen,[1] but it also contains a small per cent of other substances, such as water-vapor, carbon dioxid, and argon. All of the regular constituents of the atmosphere are gases, and these, as compared with liquids and solids, are very light. Nevertheless the atmosphere has weight and, on this account, exerts pressure upon everything on the earth. At the sea level, its pressure is nearly fifteen pounds to the square inch. The atmosphere forms an essential part of one's physical environment and serves various purposes. The process

[1] Oxygen forms about 21 per cent of the atmosphere, nitrogen about 78 per cent, carbon dioxid about .03 per cent, and the recently discovered element argon about 1 per cent. The oxygen is in a *free*, or uncombined, condition — the form in which it can be used in the body.

by which gaseous materials are made to pass between the body and the atmosphere is known as

Respiration. — As usually defined, respiration, or breathing, consists of two simple processes — that of taking air into special contrivances in the body, called the lungs, and that of expelling air from the lungs. The first process is known as *inspiration;* the second as *expiration.* We must, however, distinguish between respiration by the lungs, called *external respiration,* and respiration by the cells, called *internal respiration.*

The purpose of respiration is indicated by the changes that take place in the air while it is in the lungs. Air entering the lungs in ordinary breathing parts with about five per cent of itself in the form of oxygen and receives about four and one half per cent of carbon dioxid, considerable water-vapor, and a small amount of other impurities. These changes suggest a twofold purpose for respiration:

1. To obtain from the atmosphere the supply of oxygen needed by the body.

2. To transfer to the atmosphere certain materials (wastes) which must be removed from the body.

The chief organs concerned in the work of respiration are

The Lungs. — The lungs consist of two sac-like bodies suspended in the thoracic cavity, and occupying all the space not taken up by the heart. They are not simple sacs, however, but are separated into numerous divisions, as follows:

1. The lung on the right side of the thorax, called the right lung, is made up of three divisions, or *lobes,* and the left lung is made up of two lobes.

2. The lobes on either side are separated into smaller

divisions, called *lobules* (Fig. 34). Each lobule receives a distinct division of an air tube and has in itself the structure of a miniature lung.

3. In the lobule the air tube divides into a number of smaller tubes, each ending in a thin-walled sac, called an *infundibulum*. The interior of the infundibulum is separated into many small spaces, known as the *alveoli*, or air cells.

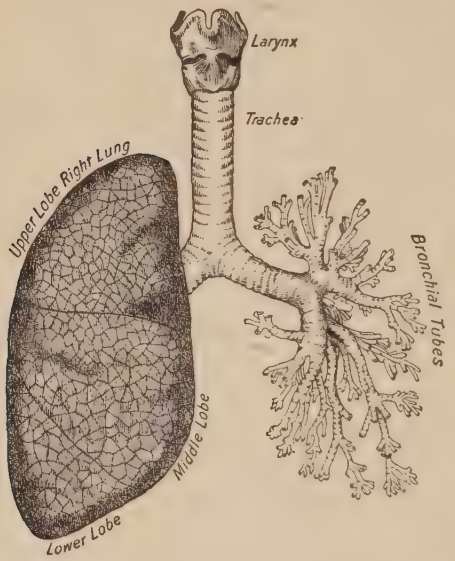

FIG. 34. — **Lungs and air passages** seen from the front. The right lung shows the lobes and their divisions, the lobules. The tissue of the left lung has been dissected away to show the air tubes.

The lungs are remarkable for their lightness and delicacy of structure.[1] They consist chiefly of the tissues that form their sacs, air tubes, and blood vessels; the membranes that line their inner and outer surfaces; and the connective tissue that binds these parts together. All these tissues are more or less elastic. The relation of the different parts of the lungs to

[1] The peculiar work devolving upon the organs of respiration necessitates a special plan of construction — one adapted to the properties of the atmosphere. Being concerned in the movement of air, a gaseous substance, they will naturally have a structure different from the organs of circulation which move a liquid (the blood). All the organs of the body are adapted by their structure to the work which they perform.

each other and to the outside atmosphere will be seen through a study of the

Air Passages. — The air passages consist of a system of tubes which form a continuous passageway between the outside atmosphere and the different divisions of the lungs. The air passes through them as it enters and leaves the lungs, a fact which accounts for the name.

The incoming air first enters the *nostrils*. These consist of two narrow passages lying side by side in the nose, and connecting with the pharynx behind. The lining of the nostrils, called *mucous membrane*, is quite thick, and has its surface much extended by reason of being spread over some thin, scroll-shaped bones that project into the passage. This membrane is well supplied with blood vessels and secretes a considerable quantity of liquid. Because of the nature and arrangement of the membrane, the nostrils are able to *warm* and *moisten* the incoming air, and to *free it from dust particles*, preparing it, in this way, for entrance into the lungs (Fig. 35).

FIG. 35. — **Model of section through the head**, showing upper air passages and other parts. 1. Left nostril. 2. Pharynx. 3. Tongue and cavity of mouth. 4. Larynx. 5. Trachea. 6. Esophagus.

The nostrils are separated from the mouth by a thin layer of bone, and back of both the mouth and the nostrils is the pharynx. The *pharynx* and the *mouth* serve as parts of the food canal, as well as air passages, and are

described in connection with the organs of digestion (Chapter XIII). Air entering the pharynx, either by the nostrils or by the mouth, passes through it into the *larynx*. The larynx, being the special organ for the production of the voice, is described later (Chapter XXVIII). The entrance into the larynx is guarded by a movable lid of cartilage, called the *epiglottis*, which prevents food particles and liquids, on being swallowed, from passing into the lower air tubes. The relations of the nostrils, mouth, pharynx, and larynx are shown in Fig. 35.

From the larynx the air enters the *trachea*, or windpipe. This is a straight and nearly round tube, slightly less than an inch in diameter and about four and one half inches in length. Its walls contain from sixteen to twenty C-shaped, cartilaginous rings, one above the other and encircling the tube. These incomplete rings, with their openings directed backward, are held in place by thin layers of connective and muscular tissue. At the lower end the trachea divides into two branches, called the bronchi, each of which closely resembles it in structure. Each *bronchus* separates into a number of smaller divisions, called the *bronchial tubes*, and these in turn divide into still smaller branches, known as the *lesser bronchial tubes* (Fig. 34). The lesser bronchial tubes, and the branches into which they separate, are the smallest of the air tubes. One of these joins, or expands into, each of the minute lung sacs, or infundibula. Mucous membrane lines all of the air passages.

General Condition of the Air Passages. — One necessary condition for the movement of the air into and from the lungs is an unobstructed passageway.[1] The air passages

[1] In ordinary inspirations the force that causes the air to move through the passages is scarcely an ounce to the square inch, while in forced inspirations it does not exceed half a pound. On this account the closing of any of the air pas-

must be kept open and free from obstructions. They are *kept open* by special contrivances found in their walls which, by supplying a degree of stiffness, cause the tubes to keep their form. In the trachea, bronchi, and larger bronchial tubes, the stiffness is supplied by rings of cartilage, while in the smaller tubes this is replaced by connective and muscular tissue. The walls of the larynx contain strips and plates of cartilage; while the nostrils and the pharynx are kept open by their bony surroundings.

The air passages are *kept clean* by cells especially adapted to this purpose, known as the *ciliated epithelial cells*. These are slender, wedge-shaped cells which have projecting from a free end many small, hair-like bodies, called *cilia* (Fig. 36). They line the mucous membrane in most of the air passages, and are so placed that the cilia project into the tubes. Here they keep up an inward and outward wave-like movement, which is quicker and has greater force in the *outward* direction. By this means the cilia are able to move small pieces of foreign matter, such as dust particles and bits of partly dried mucus, called phlegm, to places where they can be easily expelled from the lungs.[1]

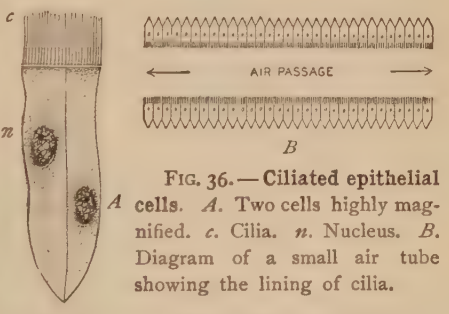

FIG. 36. — **Ciliated epithelial cells.** *A*. Two cells highly magnified. *c*. Cilia. *n*. Nucleus. *B*. Diagram of a small air tube showing the lining of cilia.

sages by pressure, or by the presence of foreign substances, would keep the air from reaching some part of the lungs.

[1] Coughing, which is a forceful expulsion of air, has for its purpose the ejection of foreign substances from the throat and lungs. Sneezing, on the other hand, has for its purpose the cleansing of the nostrils. In coughing, the air is expelled through the mouth, while in sneezing it is expelled through the nostrils.

The Alveoli. — The alveoli, or air cells, are the small divisions of the infundibula (Fig. 37). They are each about one one-hundredth of an inch ($\frac{1}{4}$ mm.) in diameter, being formed by the infolding of the infundibular wall. This wall, which has for its framework a thin layer of elastic connective tissue, supports a dense network of capillaries (Fig. 38), and is lined by a single layer of cells placed edge to edge. By this arrangement the air within the alveoli is brought very near a large surface of blood, and the exchange of gases between the air and the blood is made possible. It is at the alveoli that the oxygen passes from the air into the blood, and the carbon dioxide passes from the blood into the air. At no place in the lungs, however, do the air and the blood come in direct contact. Their exchanges must in all cases take place through the capillary walls and the layer of cells lining the alveoli.

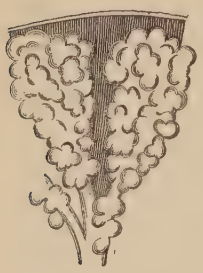

FIG. 37. — **Terminal air sacs.** The two large sacs are infundibula; the small divisions are alveoli. (Enlarged.)

Blood Supply to the Lungs. — To accomplish the purposes of respiration, not only the air, but the blood also, must be passed into and from the lungs. The chief

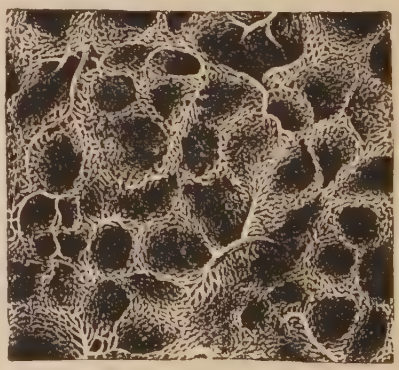

FIG. 38. — **Inner lung surface** (magnified), the blood vessels injected with coloring matter. The small pits are alveoli, and the vessels in their walls are chiefly capillaries.

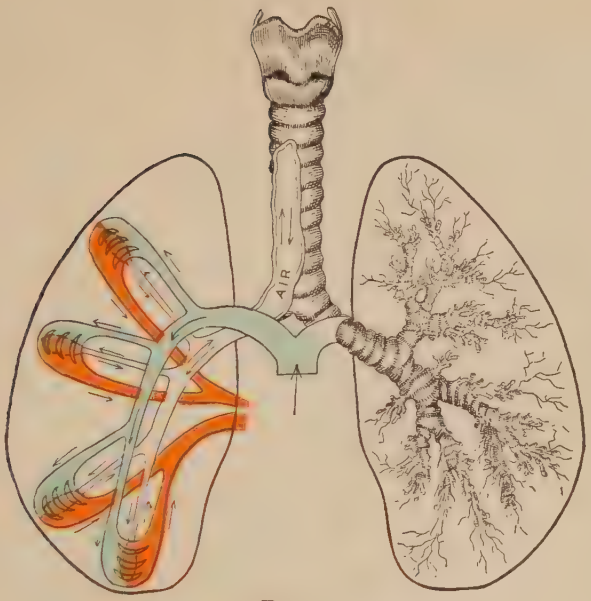

FIG. 39.

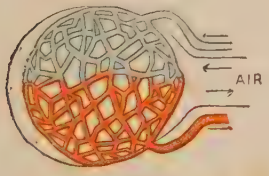

FIG. 40.

FIG. 39.— **Diagram to show the double movement of air and blood through the lungs.** The blood leaves the heart by the pulmonary artery and returns by the pulmonary veins. The air enters and leaves the lungs by the same system of tubes.

FIG. 40.— **Diagram to show air and blood movements in a terminal air sac.** While the air moves into and from the space within the sac, the blood circulates through the sac walls.

artery conveying blood to the lungs is the *pulmonary artery*. This starts at the right ventricle and by its branches conveys blood to the capillaries surrounding the alveoli in all parts of the lungs. The branches of the pulmonary artery lie alongside of, and divide similarly to, the bronchial tubes. At the places where the finest divisions of the air tubes enter the infundibula, the little arteries branch into the capillaries that penetrate the infundibular walls (Figs. 39 and 40). From these capillaries the blood is conveyed by the pulmonary veins to the left auricle.

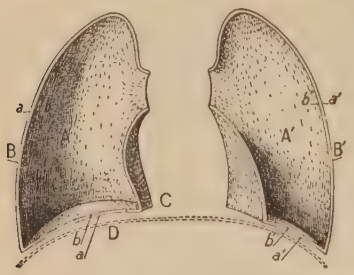

FIG. 41. — **The pleuræ**. Diagram showing the general form of the pleural sacs as they surround the lungs and line the inner surfaces of the chest (other parts removed). *A*, *A'*. Places occupied by the lungs. *B*, *B'*. Slight space within the pleural sacs containing the pleural secretion. *a*, *a'*. Outer layer of pleura and lining of chest walls and upper surface of diaphragm. *b*, *b'*. Inner layer of pleura and outer lining of lungs. *C*. Space occupied by the heart. *D*. Diaphragm.

The lungs also receive blood from two (in some individuals three) small arteries branching from the aorta, known as the *bronchial arteries*. These convey to the lungs blood that has already been supplied with oxygen, passing it into the capillaries in the walls of the bronchi, bronchial tubes, and large blood vessels, as well as the connective tissue between the lobes of the lungs. This blood leaves the lungs partly by the bronchial veins and partly by the pulmonary veins. No part of the body is so well supplied with blood as the lungs.

The Pleura. — The pleura is a thin, smooth, elastic, and tough membrane which covers the outside of the lungs and lines the inside of the chest walls. The covering of each lung is continuous with the lining of the chest wall on its respective side and forms with it a closed sac by

which the lung is surrounded, the arrangement being similar to that of the pericardium. Properly speaking, there are two pleuræ, one for each lung, and these, besides inclosing the lungs, partition off a middle space which is occupied by the heart (Fig. 40). They also cover the upper surface of the diaphragm, from which they deflect upward, blending with the pericardium. A small amount of liquid is secreted by the pleura, which prevents friction as the surfaces glide over each other in breathing.

The Thorax. — The force required for breathing is supplied by the box-like portion of the body in which the lungs are placed. This is known as the thorax, or chest, and includes that part of the trunk between the neck and the abdomen. The space which it incloses, known as the thoracic cavity, is a *variable* space and the walls surrounding this space are *air-tight.* A framework for the thorax is supplied by the ribs which connect with the spinal column behind and with the sternum, or breast-bone, in front. They form joints with the spinal column, but connect with the sternum by strips of cartilage. The ribs do not encircle the cavity in a horizontal direction, but slope downward from the spinal column both toward the front and toward the sides, this being necessary to the service which they render in breathing.

How Air is Brought into and Expelled from the Lungs. — The principle involved in breathing is that air flows from a place of *greater* to a place of *less* pressure. The construction of the thorax and the arrangement of the lungs within it provide for the application of this principle in a most practical manner. The lungs are suspended from the upper portion of the thoracic cavity, and the trachea and the upper air passages provide the only opening to the outside atmosphere. Air entering the thorax must on

this account pass into the lungs. As the thorax is enlarged the air in the lungs expands, and there is produced within them a place of *slightly less* air pressure than that of the atmosphere on the outside of the body. This difference causes the air to flow into the lungs.

When the thorax is diminished in size, the air within the lungs is slightly compressed. This causes it to become denser and to exert on this account a pressure *slightly greater* than that of the atmosphere on the outside. The air now flows out until the equality of the pressure is again restored. Thus the thorax, by making the pressure within the lungs first slightly less and then slightly greater than the atmospheric pressure, causes the air to move into and out of the lungs.

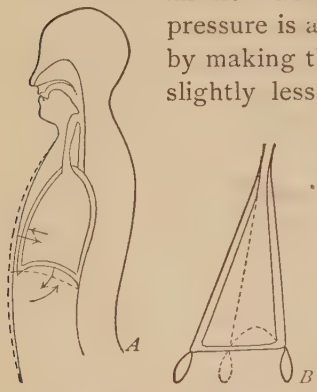

FIG. 42.—**Diagram illustrating the bellows principle in breathing.** *A.* The human bellows. *B.* The hand bellows. Compare part for part.

Breathing is well illustrated by means of the common hand bellows, its action being similar to that of the thorax. It will be observed that when the sides are spread apart air flows into the bellows. When they are pressed together the air flows out. If an air-tight sack were hung in the bellows with its mouth attached to the projecting tube, the arrangement would resemble closely the general plan of the breathing organs (Fig. 42). One respect, however, in which the bellows differs from the thorax should be noted. The thorax is never sufficiently compressed to drive out all the air. Air is always present in the lungs. This keeps them more or less distended and pressed against the thoracic walls.

How the Thoracic Space is Varied.—One means of varying the size of the thoracic cavity is through the movements of the ribs and their resultant effect upon the walls

of the thorax. In bringing about these movements the following muscles are employed:

1. The *scaleni* muscles, three in number on each side, which connect at one end with the vertebræ of the neck and at the other with the first and second ribs. Their contraction slightly raises the upper portion of the thorax.

2. The *elevators of the ribs*, twelve in number on each side, which are so distributed that each single muscle is attached, at one end, to the back portion of a rib and, at the other, to a projection of the vertebra a few inches above. The effect of their contraction is to elevate the middle portion of the ribs and to turn them outward or spread them apart.

3. The *intercostal* muscles, which form two thin layers between the ribs, known as the *internal* and the *external* intercostal muscles. The external intercostals are attached between the outer lower margin of the rib above and the outer upper margin of the rib below, and extend obliquely downward and forward. The internal intercostals are attached between the inner margins of adjacent ribs, and they extend obliquely downward and backward from the front. The contraction of the external intercostal muscles raises the ribs, and the contraction of the internal intercostals tends to lower them.

By slightly raising and spreading apart the ribs the thoracic space is increased in two directions — from front

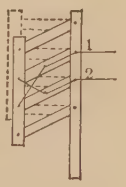

FIG. 43. — **Simple apparatus** for illustrating effect of movements of the ribs upon the thoracic space; strips of cardboard held together by pins, the front part being raised or lowered by threads moving through attachments at 1 and 2. As the front is raised the space between the uprights is increased. The front upright corresponds to the breastbone, the back one to the spinal column, the connecting strips to the ribs, and the threads to the intercostal muscles.

to back and from side to side. Lowering and converging the ribs has, of course, the opposite effect (Fig. 43). Except in forced expirations the ribs are lowered and converged by their own weight and by the elastic reaction of the surrounding parts.

The Diaphragm. — Another means of varying the thoracic space is found in an organ known as the diaphragm. This is the dome-shaped, *movable partition* which separates the thoracic cavity from the cavity of the abdomen. The edges of the diaphragm are firmly attached to the walls of the trunk, and the center is supported by the pericardium and the pleura. The outer margin is muscular, but the central portion consists of a strong sheet of connective tissue. By the contraction of its muscles the diaphragm is pulled down, thereby increasing the thoracic cavity. By raising the diaphragm the thoracic cavity is diminished.

The diaphragm, however, is not raised by the contraction of its own muscles, but is *pushed up* by the organs beneath. By the elastic reaction of the abdominal walls (after their having been pushed out by the lowering of the diaphragm), pressure is exerted on the organs of the abdomen and these in turn press against the diaphragm. This crowds it into the thoracic space. In forced expirations the muscles in the abdominal walls contract to push up the diaphragm.

Interchange of Gases in the Lungs. — During each inspiration the air from the outside fills the entire system of bronchial tubes, but the alveoli are largely filled, at the same time, by the air which the last expiratory effort has left in the passages. By the action of currents and eddies and by the rapid diffusion of gas particles, the air from the outside mixes with that in the alveoli and comes in contact with the membranous walls. Here the oxygen, after being dissolved by the moisture on the membrane, diffuses into the blood. The carbon dioxid, on the other hand, being in excess in the blood, diffuses toward the air in the alveoli.

Summary. — The purpose of respiration is to bring about an exchange of gases between the body and the atmosphere. The organs employed for this purpose, called the respiratory organs, are adapted to handling materials in the *gaseous* state, and are operated in accordance with principles governing the movements of the atmosphere. By alternately increasing and diminishing the thoracic space, air is made to pass between the outside atmosphere and the interior of the lungs. Finding its way into the smallest divisions of the lungs, called the alveoli, the air comes very near a large surface of blood. By this means the carbon dioxid diffuses out of the blood, and the free oxygen enters. Through the combined action of the organs of respiration and the organs that move the blood and the lymph, the cells in all parts of the body are enabled to exchange certain gaseous materials with the outside atmosphere.

Exercises. — 1. How does air entering the lungs differ in composition from air leaving the lungs? What purposes of respiration are indicated by these differences?

2. Name the divisions of the lungs.

3. Trace air from the outside atmosphere into the alveoli. Trace the blood from the right ventricle to the alveoli and back again to the left auricle.

4. How does the movement of air into and from the lungs differ from that of the blood through the lungs with respect to (*a*) the direction of the motion, (*b*) the causes of the motion, and (*c*) the tubes through which the motion takes place?

5. How are the air passages kept clean and open?

6. Describe the pleura. Into what divisions does it separate the thoracic cavity?

7. Describe and name uses of the diaphragm.

8. If 25 cubic inches of air are passed into the lungs at each inspiration and .05 of this is retained as oxygen, calculate the number of cubic feet of oxygen consumed each day, if the number of inspirations be 18 per minute.

9. Find the *weight* of a day's supply of oxygen, as found in the above problem, allowing 1.3 ounces as the weight of a cubic foot.

PRACTICAL WORK

Examine a dissectible model of the chest and its contents (Fig. 44). Note the relative size of the two lungs and their position with reference to the heart and diaphragm. Compare the side to side and vertical diameters of the cavity. Trace the air tubes from the trachea to their smallest divisions.

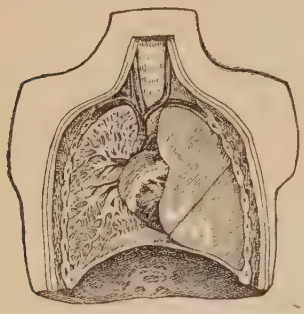

FIG. 44. — **Model** for demonstrating the lungs.

Observation of Lungs (Optional). — Secure from a butcher the lungs of a sheep, calf, or hog. The windpipe and heart should be left attached and the specimen kept in a moist condition until used. Demonstrate the trachea, bronchi, and the bronchial tubes, and the general arrangement of pulmonary arteries and veins. Examine the pleura and show lightness of lung tissue by floating a piece on water.

To Show the Changes That Air Undergoes in the Lungs. — 1. Fill a quart jar even full with water. Place a piece of cardboard over its mouth and invert, without spilling, in a pan of water. Inserting a tube under the jar, blow into it air that has been held as long as possible in the lungs. When filled with air, remove the jar from the pan, keeping the top well covered. Slipping the cover slightly to one side, insert a burning splinter and observe that the flame is extinguished. This proves the absence of sufficient oxygen to support combustion. Pour in a little limewater [1] and shake to mix with the air. The change of the limewater to a milky white color proves the presence of carbon dioxid.

[1] To prepare limewater some small lumps of *fresh* lime (either slacked or unslacked) are added to a large bottle of water and thoroughly shaken. This is put *aside* until the lime all settles to the bottom and the water above is perfectly clear. This is now ready for use and may be poured off as needed. When the supply is exhausted add more water and shake again.

2. The effects illustrated in experiment 1 may be shown in a somewhat more striking manner as follows: Fill two bottles of the same size each one-fourth full of limewater and fit each with a two-holed rubber stopper (Fig. 45). Fit into each stopper one short and one long glass tube, the long tube extending below the limewater. Connect the short tube of one bottle and the long tube of the other bottle with a Y-tube. Now breathe slowly three or four times through the Y-tube. It will be found that the inspired air passes through one bottle and the expired air through the other. Compare the effect upon the limewater in the two bottles. Insert a small burning splinter into the top of each bottle and note the result. What differences between inspired and expired air are thus shown?

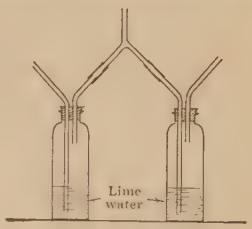

FIG. 45. — **Apparatus** for showing changes which air undergoes while in the lungs.

3. Blow the breath against a cold window pane. Note and account for the collection of moisture.

4. Note the temperature of the room as shown by a thermometer. Now breathe several times upon the bulb, noting the rise in the mercury. What does this experiment show the body to be losing through the breath?

To Show Changes in the Thoracic Cavity. — 1. To a yard- or meter-stick, attach two vertical strips, each about eight inches long,

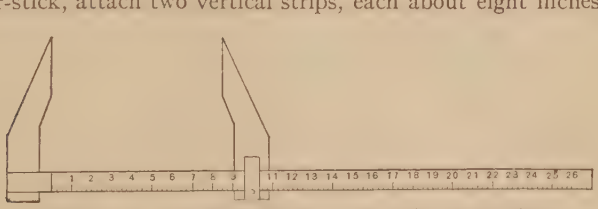

FIG. 46. — **Apparatus** for measuring chest expansion.

as shown in Fig. 46. The piece at the end should be secured firmly in place by screws or nails. The other should be movable. With this contrivance measure the sideward and forward expansion of a boy's thorax. Take the diameter first during a complete inspiration and then during a complete expiration, reading the difference. Compare the forward with the sideward expansion.

2. With a tape-line take the circumference of the chest when all the air possible has been expelled from the lungs. Take it again when the lungs have been fully inflated. The difference is now read as the chest expansion.

To Illustrate the Action of the Diaphragm. — Remove the bottom from a large bottle having a small neck. (Scratch a deep mark with a file and hold on the end of this mark a hot poker. When the glass cracks, lead the crack around the bottle by heating about one-half inch in advance of it.) Place the bottle in a large glass jar filled two-thirds full of water (Fig. 47). Let the space above the water represent the chest cavity and the water surface represent the diaphragm. Raise the bottle, noting that the water falls, thereby increasing the space and causing air to enter. Then lower the bottle, noting the opposite effect.

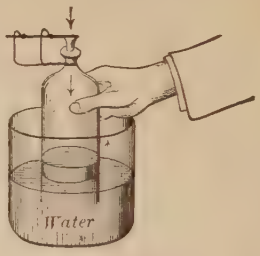

FIG. 47. — **Simple apparatus** for illustrating the action of the diaphragm.

To show the movement of the air in and out of the bottle, hold with the hand (or arrange a support for) a burning splinter over the mouth of the bottle.

To Estimate the Capacity of the Lungs. — Breathing as naturally as possible, expel the air into a spirometer (lung tester) during a period, say, of ten respirations (Fig. 48). Note the total amount of air exhaled and the number of "breaths," and calculate the amount of air exhaled at each breath. This is called the *tidal* air.

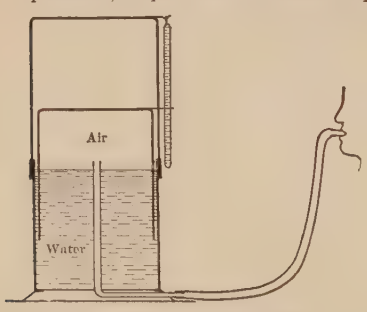

FIG. 48. — **Apparatus** (Spirometer) for measuring the capacity of the lungs.

2. After an ordinary inspiration empty the lungs as completely as possible into the spirometer, noting the quantity exhaled. This amount, less the tidal air, is known as the *reserve* air. The air which is now left in the lungs is called the *residual* air. On the theory that this is equal in amount to the reserve air, calculate the capacity of the lungs in an ordinary inspiration.

3. Now fill the lungs to the full expansion of the chest and empty them as completely as possible into the spirometer, noting the amount expelled. This, less the tidal air and the reserve air, is called the *complemental* air. Now calculate the total capacity of the lungs.

NOTE. — In calculating the capacity of the lungs according to the above experiment, we should keep the following facts in mind:

1. The air that flows into and from the lungs in ordinary breathing is called the *tidal air*.

2. The air that remains in the lungs after all that can has been expelled is called the *residual air*.

3. The air that can be forced from the lungs when they are ordinarily full, less the tidal air, is the *reserve air*.

4. The amount of air that can be taken by extra effort above what they hold when ordinarily full, is the *complemental air*.

In the average individual the total capacity of the lungs (with the chest in repose) is about one gallon or 231 cubic inches. In forced inspirations this capacity may be increased about one-third, or to about 310 cubic inches.

CHAPTER X

PASSAGE OF OXYGEN THROUGH THE BODY

WHAT is the nature of oxygen? What is its purpose in the body and how does it serve this purpose? How is the blood able to take it up at the lungs and give it off at the cells? What becomes of it after being used? These are questions touching the maintenance of life and they deserve careful consideration.

Nature of Oxygen. — To understand the relation which oxygen sustains to the body we must acquaint ourselves with certain of its chemical properties. It is an element[1] of intense affinity, or combining power, and is one of the most active of all chemical agents. It is able to combine with most of the other elements to form chemical compounds. A familiar example of its combining action is found in ordinary combustion, or burning. On account of the part it plays in this process, oxygen is called the *supporter of combustion;* but it supports combustion by the simple method of uniting. The ashes that are left and the invisible gases that escape into the atmosphere are the compounds formed by the uniting process. It thus appears that oxygen, in common with the other elements, may exist in either of two forms:

[1] An *element* is a single kind of matter. Those substances are classed as elements which cannot be separated into different kinds of matter. Two or more elements combined in definite proportions by weight form a *compound*. The elements are few in number, only about eighty being known. Compounds, on the other hand, are exceedingly numerous.

1. That in which it is in a *free*, or uncombined, condition — the form in which it exists in the atmosphere.

2. That in which it is a part of compounds, such as the compounds formed in combustion.

Oxygen manifests its activity to the best advantage when it is in a free state, or, more accurately speaking, when it is passing from the free state into one of combination. It is separated from its compounds and brought again into a free state by overcoming with heat, or some other force, the affinity which causes it to unite.

How Oxygen unites. — The chemist believes oxygen, as well as all other substances, to be made up of exceedingly small particles, called *atoms*. The atoms do not exist singly in either elements or compounds, but are united with each other to form groups of atoms that are called *molecules*. In an element the molecules are made up of one kind of atoms, but in a compound the molecules are made up of as many kinds of atoms as there are elements in the compound. Changes in the composition of substances (called chemical changes) are due to rearrangements of the atoms and the formation of new molecules. The atoms, therefore, are the units of chemical combination. In the formation of new compounds they unite, and in the breaking up of existing compounds they separate.

The uniting of oxygen is no exception to this general law. All of its combinations are brought about by the uniting of its atoms. In the burning of carbon, for example, the atoms of oxygen and the atoms of carbon unite, forming molecules of the compound known as carbon dioxid. The chemical formula of this compound, which is CO_2, shows the proportion in which the atoms unite — one atom of carbon uniting with two atoms of oxygen in each of the molecules. The affinity of oxygen for other

elements, and the affinity of other elements for oxygen, and for each other, resides in their atoms.

Oxidation. — The uniting of oxygen with other elements is termed *oxidation.* This may take place slowly or rapidly, the two rates being designated as *slow* oxidation and *rapid* oxidation. Examples of slow oxidation are found in certain kinds of decay and in the rusting of iron. Combustion is an example of rapid oxidation. Slow and rapid oxidation, while differing widely in their effects upon surrounding objects, are alike in that both produce heat and form compounds of oxygen. In slow oxidation, however, the heat may come off so gradually that it is not observed.

Movement of Oxygen through the Body. — Oxygen has been shown in the preceding chapters to pass from the lungs into the blood and later to leave the blood and, passing through the lymph, to enter the cells. That oxygen does not become a permanent constituent of the cells is shown by the constancy of the body weight. Nearly two pounds of oxygen per day are known to enter the cells of the average-sized person. If this became a permanent part of the cells, the body would increase in weight from day to day. Since the body weight remains constant, or nearly so, we must conclude that oxygen leaves the body about as fast as it enters. Oxygen enters the body as a *free* element. The form in which it leaves the body will be understood when we realize the purpose which it serves and the method by which it serves this purpose.

Purpose of Oxygen in the Body. — The question may be raised: Is it possible for oxygen to serve a purpose in the body without remaining in it? This, of course, depends upon what the purpose is. That it is possible for oxygen to serve a purpose and at the same time pass on through

the place where it serves that purpose, is seen by studying the combustion in an ordinary stove (Fig. 49). Oxygen enters at the draft and for the most part passes out at the flue, but in passing through the stove it unites with, or oxidizes, the fuel, causing the combustion which produces the heat.

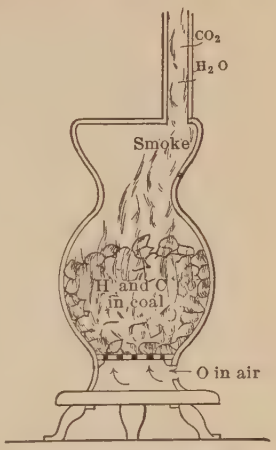

FIG. 49.—**Coal stove** illustrating rapid oxidation.

Now it is found that certain chemical processes, mainly oxidations, are taking place in the body. These produce the heat for keeping it warm and also supply other forms of energy,[1] including motion. It is the purpose of oxygen to keep up these oxidations and, by so doing, to aid in supplying the body with energy. It serves this purpose in much the same way that it supports combustion, *i.e.*, by uniting with, or oxidizing, materials derived from foods that are present in the cells.

Does Oxygen serve Other Purposes? — It has been suggested that oxygen may serve the purpose of oxidizing, or destroying, substances that are injurious and of acting, in this way, as a purifying agent in the body. In support of this view is the natural tendency of oxygen to unite with substances and the well-known fact that oxygen is an important natural agent in purifying water. It seems probable, therefore, that it may to a slight extent serve this purpose in the body. It is probable also that oxygen aids through its chemical activity in the formation of compounds

[1] The term *energy*, as used here, has the same general meaning as the word *power*. See Chapter XVII.

which are to become a part of the cells. Both of these uses, however, are of minor importance when compared with *the main use of oxygen*, which *is that of an aid in supplying energy to the body*.

Oxygen and the Maintenance of Life. — In the supplying of energy to the body, one of the conditions necessary to the maintenance of life is provided. Because oxygen is necessary to this process, and because death quickly results when the supply of it is cut off, oxygen is frequently called the supporter of life. This idea is misleading, for oxygen has no more to do with the maintenance of life than have the food materials with which it unites. Life appears to be more dependent upon oxygen than upon food, simply because the supply of it in the body at any time is exceedingly small. Being continually surrounded by an atmosphere containing free oxygen, the body depends upon this as a constant source of supply, and does not store it up. Food, on the other hand, is taken in excess of the body's needs and stored in the various tissues, the supply being sufficient to last for several days. When the supply of either oxygen or food is exhausted in the body, life must cease.

The Oxygen Movement a Necessity. — Since *free* oxygen is required for keeping up the chemical changes in the cells, and since it ceases to be free as soon as it goes into combination, its continuous movement through the body is a necessity. The oxygen compounds must be removed as fast as formed in order to make room for more free oxygen. This movement has already been studied in connection with the blood and the organs of respiration, but the consideration of certain details has been deferred till now. By what means and in what form is the oxygen passed *to* and *from* the cells?

Passage of Oxygen through the Blood. — In serving its purpose at the cells, the oxygen passes twice through the blood — once as it goes toward the cells and again as it passes from the cells to the exterior of the body:

Passage toward the Cells. — This is effected mainly through the hemoglobin of the red corpuscles. At the lungs the oxygen and the hemoglobin form a weak chemical compound that breaks up and liberates the oxygen when it reaches the capillaries in the tissues. The separation of the oxygen from the hemoglobin at the tissues appears to be due to two causes: first, to the weakness of the chemical attraction between the atoms of oxygen and the atoms that make up the hemoglobin molecule; and second, to a difference in the so-called *oxygen pressure* at the lungs and at the tissues.[1]

The attraction of the oxygen and the hemoglobin is sufficient to cause them to unite where the oxygen pressure is more than one half pound to the square inch, but it is not sufficiently strong to cause them to unite or to prevent their separation, if already united, where the oxygen pressure is less than one half pound to the square inch. The oxygen pressure at the lungs, which amounts to nearly three pounds to the square inch, easily causes the oxygen and the hemoglobin to unite, while the almost complete absence of any oxygen pressure at the tissues, permits their separation. The blood in its circulation constantly flows from the place of high oxygen pressure at the lungs

[1] The oxygen pressure of the atmosphere is that portion of the total atmospheric pressure which is due to the weight of the oxygen. Since oxygen comprises about one fifth of the atmosphere, the pressure which it exerts is about one fifth of the total atmospheric pressure, or, at the sea level, about three pounds to the square inch ($15 \times \frac{1}{5} = 3$). This is the oxygen pressure of the atmosphere. The low oxygen pressure in the tissues is due to its scarcity, and this scarcity is due to its entering into combination at the cells.

to the place of low oxygen pressure at the tissues and, in so doing, loads up with oxygen at one place and unloads it at the other (Fig. 50).

Passage from the Cells. — Since oxygen leaves the free state at the cells and becomes a part of compounds, we are able to trace it from the body only by following the course of these compounds. Three waste compounds of importance are formed at the cells — carbon dioxid (CO_2), water (H_2O), and urea (N_2H_4CO). The first is formed by the union of oxygen with carbon, the second by its union with

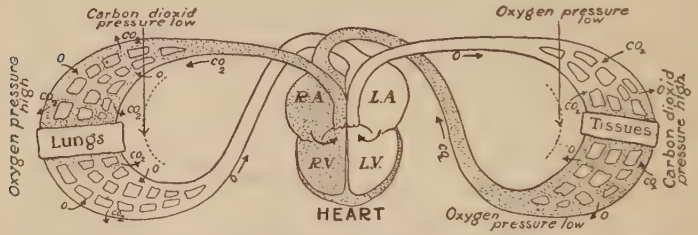

FIG. 50. — **Diagram illustrating movement of oxygen and carbon dioxid through the body** (T. D. Magers). Each moves from a place of relatively high to a place of relatively low pressure. (See text.)

hydrogen, and the third by its union with nitrogen, hydrogen, and carbon. These compounds are carried by the blood to the organs of excretion, where they are removed from the body. The water leaves the body chiefly as a liquid, the urea as a solid dissolved in water, and the carbon dioxid as a gas. The passage of carbon dioxid through the blood requires special consideration.

Passage of Carbon Dioxid through the Blood. — Part of the carbon dioxid is dissolved in the plasma of the blood, and part of it is in weak chemical combination with substances found in the plasma and in the corpuscles. Its passage through the blood is accounted for in the same

way as the passage of the oxygen. Its ability to dissolve in liquids and to enter into chemical combination varies as the *carbon dioxid pressure*.[1] This in turn varies with the amount of the carbon dioxid, which is greatest at the cells (where it is formed), less in the blood, and still less in the lungs. Because of these differences, the blood is able to take it up at the cells and release it at the lungs (Fig. 50).

FIG. 51. — **Soap bubble** floating in a vessel of carbon dioxid, illustrating the difference in weight between air and carbon dioxid gas.

Properties of Carbon Dioxid. — Carbon dioxid is a colorless gas with little or no odor. It is classed as a heavy gas, being about one-third heavier than air[2] (Fig. 51). It does not support combustion, but on the contrary is used to some extent to extinguish fires. It is formed by the oxidation of carbon in the body, and by the combustion of carbon outside of the body. It is also formed by the decay of animal and vegetable matter. From these sources it is continually finding its way into the atmosphere. Although not a poisonous gas, carbon dioxid may, if it surrounds the body, shut out the supply of oxygen and cause death.[3]

[1] See footnote on oxygen pressure, page 103.

[2] The impression prevails to some extent that carbon dioxid, on account of its weight, settles out of the atmosphere, collecting in old wells and at the floor in crowded rooms. Any such settling of the carbon dioxid is prevented by the rapid motion of its molecules. This motion not only prevents a separation of carbon dioxid and air after they are mixed, but causes them to mix rapidly when they are separated, if they still have surface contact. The carbon dioxid found in old wells is formed there by decaying vegetable or animal matter. In rooms it is no more abundant at the floor than in other parts.

[3] On account of the formation of carbon dioxid in places containing decaying material, the descent into an old well or other opening into the earth is often a hazardous undertaking. Before making such a descent the air should always be tested by lowering a lighted lantern or candle. Artificial respiration is the only means of restoring one who has been overcome by this gas (page 118).

Final Disposition of Carbon Dioxid. — It is readily seen that the union of carbon and oxygen, which is continually removing oxygen from the air and replacing it with carbon dioxid, tends to make the whole atmosphere deficient in the one and to have an excess of the other. This tendency is counteracted through the agency of vegetation. Green plants absorb the carbon dioxid from the air, decompose it, build the carbon into compounds (starch, etc.) that become a part of the plant, and return the free oxygen to the air (Fig. 52). In doing this, they not only preserve the necessary proportion of oxygen and carbon dioxid in the atmosphere, but also put the carbon and oxygen in such a condition that they can again unite. The force which enables the plant cells to decompose the carbon dioxid is supplied by the sunlight (Chapter XVII).

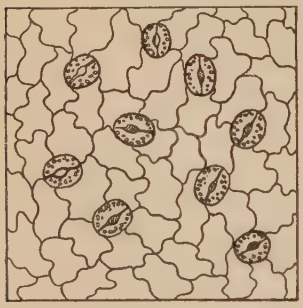

FIG. 52. — **Under surface** of a geranium leaf showing breathing pores, highly magnified (M. H.).

Summary. — Oxygen, by uniting with materials at the cells, keeps up a condition of chemical activity (oxidation) in the body. This supplies heat and the other forms of bodily energy. Entering as a free element, oxygen leaves the body as a part of the waste compounds which it helps to form. The free oxygen is transported from the lungs to the cells by means of the hemoglobin of the red corpuscles, while the combined oxygen in carbon dioxid and other compounds from the cells is carried mainly by the plasma. The limited supply of free oxygen in the body at any time makes necessary its continuous introduction. For a similar reason, carbon dioxid must be constantly expelled.

Exercises. — 1. Describe the properties of oxygen. How does it unite with other elements? How does it support combustion?

2. State the purpose of oxygen in the body. What properties enable it to fulfill this purpose?

3. What is the proof that oxygen does not remain permanently in the body? How does the oxygen entering the body differ from the same oxygen as it leaves the body?

4. What is the necessity for the *continuous* introduction of oxygen into the body, while food is introduced only at intervals?

5. How are the red corpuscles able to take up and give off oxygen? How is the plasma able to take up and give off carbon dioxid?

6. If twenty-five cu. ins. of air pass from the lungs at each expiration and 4.5 per cent of this is carbon dioxid, calculate the number of cubic feet of the gas expelled in twenty-four hours, estimating the number of respirations at eighteen per minute.

7. What is the weight of this volume of carbon dioxid, if one cubic foot weighs 1.79 ounces?

8. What portion of this weight is oxygen and what carbon, the ratio by weight of carbon to oxygen in carbon dioxid being 12 to 32?

9. What is the final disposition of carbon dioxid in the atmosphere?

PRACTICAL WORK

To Show the Difference between Free Oxygen and Oxygen in Combination. — Examine some crystals of potassium chlorate ($KClO_3$). They contain oxygen *in combination* with potassium and chlorine. Place a few of these in a small test tube and heat strongly in a gas or alcohol flame. The crystals first melt, and the liquid which they form soon appears to boil. If a splinter, having a spark on the end, is now inserted in the tube, it is kindled into a flame. This shows the presence of *free* oxygen.

To Prepare and Test Carbon Dioxid. — Burn a splinter in a large vessel of air, keeping the top covered. Add limewater and shake. Note and account for the result.

Place some pieces of limestone in a jar holding at least half a gallon. Barely cover with water and add hydrochloric acid until a gas is rapidly evolved. This is carbon dioxid. Test its effect upon a burning splinter and upon a soap bubble filled with air (Fig. 51).

CHAPTER XI

HYGIENE OF RESPIRATION

Our methods of living, as they affect the organs and processes of breathing, have chiefly to do with conditions referred to as the body's resistance.

Kinds of Resistance. — The body's resistance is its power to repel attacks of germs (p. 400). It appears to be of three different kinds, these being known as local resistance, general resistance, and specific resistance. By *local resistance* is meant the power of some particular part of the body to resist germ attacks and especially the power of the body surfaces. By *general resistance* is meant the power of the whole body to resist attacks of all kinds of germs, and by *specific resistance*, the power of the body to repel attacks from the germs of some particular disease, such as measles.

The liability of the lungs to attacks of such dread diseases as pneumonia and tuberculosis makes the question of resistance of the greatest importance. Against these and other diseases that attack the organs of breathing, our main defense is along the line of keeping up good local resistance and good general resistance.

Local Resistance of the Lungs and Air Passages. — Whether this is good or poor depends upon the condition of the mucous linings of these parts (p. 83). If the linings of the nose, throat, bronchial tubes, and lung sacs are smooth, have just the right amount of blood flowing through them, and are in other conditions healthy, they have good

local resistance and no kind of germs can easily get a start in them. But if they are rough and swollen and are congested (have too much blood and too little blood movement), they have a low local resistance and can easily be attacked. The problem, then, of keeping up good local resistance of the lungs and air passages is a problem of keeping their linings just as healthy as possible.

General Resistance. — The fact that we have a power to resist attacks of germs which depends on the condition of the body as a whole, was demonstrated by the great scientist, Pasteur, in the following manner: He inoculated several chickens with an animal disease, called *anthrax*. He inoculated some of the chickens when they were warm and dry, but others he first got wet and cold. He found that the anthrax germs had no effect upon the chickens that were warm and dry at the time of inoculation, but that the chickens that were wet and cold developed the disease. The bodies of the warm and dry chickens were able to resist and overcome the germs, while the bodies of those that were wet and cold had lost this power.

Similar results have been observed upon people. For example, a small boy spends the entire day skating and a day or two later develops scarlet fever. An adult comes down with typhoid fever after some days of overwork. And a nurse contracts the disease of her patient after some nights of wakeful attendance.

How Good General Resistance is Kept Up. — The plan is fully expressed in one brief sentence: *Keep up the health.* To let the health run down from any cause is to lower the general resistance, and to improve the health by any means is to improve the general resistance. But in watching over the health in general, we must avoid overwork, prolonged chilling, loss of sleep, nervous exhaustion, and other things

in everyday life that lower the tone of health for short intervals. This last point is of special importance in the prevention of pneumonia and tuberculosis.

How Pneumonia and Tuberculosis of the Lungs get their Start. — The germs of both of these diseases are too weak to attack successfully the linings of lungs that are healthy, and especially if these are backed up by a healthy body. However, if the local resistance of the lungs is low and then something happens to bring down the general resistance, they are very apt to get a start. Once started both diseases are serious, but in different ways. We must keep them from getting started by living in such manner as to keep up good local resistance of the lungs and air passages and good general resistance of the entire body.

Things in Everyday Life that Affect the Local Resistance of the Lungs and Air Passages and the General Resistance of the Whole Body. — These include,

1. Our method of sitting and standing.
2. Our clothing — whether it be of sufficient warmth and whether it be properly distributed over the body.
3. The temperature of our hands and feet.
4. Our method of sleeping.
5. Our habits of eating and drinking.
6. Outdoor life and exercise.
7. The having of colds.
8. Our method of breathing — whether full or shallow and whether we breathe through the nose or through the mouth.
9. The ventilation of our rooms.

Posture and our Resistance. — The slumped-over position cramps the chest and keeps air from penetrating to all parts of the lungs, especially the upper portions. This weakens the lungs at certain places and causes *spots of low*

resistance. The erect position, on the other hand, makes it easy for air to penetrate to all parts of the lungs and so aids in keeping all the lung surfaces healthy. Keeping the body in the right shape, as will be shown later (Chapter XX), is also a valuable aid to good health and, on this account, to good general resistance.

Clothing and the Resistance. — While the dependence of good health and good general resistance upon a proper amount of clothing is well understood, the effect of clothing that is too thin and clothing wrongly distributed over the body, upon the local resistance of the lungs and air passages, is not generally known. Clothing that is too thin for the state of the weather lets the surface chill and this drives an excess of blood into and congests the mucous linings, and clothing that is too heavy on the chest and neck and too thin on the arms, legs, and feet favors an excess flow of blood toward the upper portions of the body, including the nose, throat, and lungs (p. 75). This, as already explained, means a lower resistance of these parts.

Cold Feet and Hands and Local Resistance. — Cold extremities from lack of blood flowing into them means an increased flow to the linings of the nose, throat, and lungs. An example of the bad effects of this upon the local resistance of these parts is the taking of cold from getting the feet wet, and chilled as a consequence. One phase of right living is to keep the feet and hands comfortably warm.

The Method of Sleeping and the Resistance. — Sleeping in a warm bed in a cold bedroom, as already explained (p. 76), improves the circulation in the linings of the air passages and the lungs, and this improves their resistance. Sleeping cold at night or sleeping in a poorly ventilated room has the opposite effect. The sound sleep which is

induced by the first method is also a great aid to good health and good general resistance.

Our Habits of Eating and Drinking. — A balanced diet taken in the right amounts is, perhaps, the greatest of all our aids to good health and good general resistance. On this account, failure to supply the body with what it needs or to supply needed materials in the right amounts, is the greatest of our causes of poor health and a low general resistance. In this connection it is claimed that the daily use of pure, whole milk is an almost sure preventive of tuberculosis. For the same reason, putting something into the body that does not belong there, such as alcohol, may be followed by the most serious results to our resistance.

Pneumonia and Tuberculosis and Alcohol. — According to good medical authority, the user of alcohol is much more apt to get pneumonia and much less apt to recover, when he gets it, than the non-user. Through its bad effect upon the health, alcohol lowers the general resistance and predisposes one to an attack. On account of its weakening effect upon the heart (p. 77), it prevents recovery in many cases. The heart that has been badly weakened by the use of alcohol gives out under the heavy task of pumping blood through the badly congested lungs.

On account of its effect upon the general resistance, alcohol is one of the greatest of the causes of tuberculosis. It is claimed that pulmonary tuberculosis is more frequent in heavy drinkers than among people of moderate habits, in about the proportion of three to one.

Effects of Outdoor Air. — One going out of doors on a cold day will observe an increase in the secretions of the nostrils. This cleanses their linings and tends to destroy any germs that may be present. What is true of the nose secretions is also true to some extent of those of the throat

and the lungs. The improved secretions, together with other beneficial effects, make outdoor life one of the greatest agencies for improving the local resistance of the lungs and air passages. Proof of this is found in the results obtained from the outdoor treatment of pneumonia and tuberculosis. Combined with exercise it also increases the general resistance.

The Serious Nature of Colds. — Colds are mild diseases of a contagious nature caused by germs. Though the seat of attack is usually the nose or the throat, the more severe types, as seen in the "flu," may attack the lungs. It is in the bad effect upon the linings of the air passages that we have the worst effect of the cold, though they reduce the general resistance at the time of the attack. For several reasons we should have as few colds as possible and get over those we do have as soon, and as completely, as we can.

One must also keep in mind the possibility that what *seems to be a cold* may be the beginning of something vastly worse. Measles, whooping cough, scarlet fever, tonsillitis, diphtheria, and the "flu" are all in their beginning very much like colds. Hence if the attack is at all severe, a physician should be called at once.

To Avoid Colds. — There are about three lines of effort in doing this, as follows:

1. *That of keeping up good local resistance* of the air passages by all the methods described in this chapter.

2. *That of keeping up good general resistance* by keeping just as healthy as possible.

3. *That of avoiding people who have colds.* The cold germs are spread by those having them by a fine spray thrown from the air passages by coughing and sneezing and by loud talking and laughing, which is breathed by those

who are near. It is claimed one may " catch " a cold in this way by being within five feet of one who already has one.

To Cure the Cold Quickly and Completely. — Our aim in this case is to aid the body in its efforts to rid itself of the cold germs. We can do this in the following ways:

1. *By keeping warm.* This improves the skin circulation and relieves congestions in the mucous linings. Getting chilled does just the reverse, tending to start the cold over again.

2. *By reducing the amount of our work*, staying in bed if the cold is very severe. The energy thus saved will be used by the body in overcoming the cold.

3. *By spending more time out of doors after the active stage has passed*, but avoiding getting chilled.

4. *By avoiding the use of medicines*, except a mild laxative, if the bowels fail to move. While quinine and other drugs are sometimes taken for colds, they make the body more susceptible to future attacks. The curing of the cold by the body itself tends to give it specific resistance (p. 401) against the cold germs.

Importance of Breathing through the Nose. — Nature has provided two methods of breathing — a regular method, which is through the nose, and an emergency method, which is through the mouth. The importance of nose breathing lies in the fact that it prepares the air for entering the lungs (p. 83). The nose not only acts as a filter (Fig. 53) for cleaning the air, but it also adds warmth and moisture. Nose breathing, furthermore, has a good effect upon the voice and upon the appearance. Obstructions that prevent nose breathing are the main cause of the objectionable " nasal qualities " of the voice, and one who breathes through the mouth can hardly avoid a bad expression of

the face. And then one who does not breathe freely through the nose is very apt to snore in his sleep. Nose breathing must be well established early in life.

Remedies for Mouth Breathing. — There are two simple causes for this trouble — habit and necessity — and, of course, two simple remedies. If the cause is a bad habit, this must be corrected by constant effort to breathe in the right manner, and it may be necessary to tie the mouth shut when one is sleeping. Conditions that force one to breathe through the mouth instead of the nose may be obstructions in the nostrils or obstructions in the upper part of the pharynx. Quite frequently there are growths in the upper pharynx, called *adenoids*, which completely close the passageway. The remedy when there are obstructions either in the nostrils themselves or in the upper pharynx is a minor surgical operation for their removal.

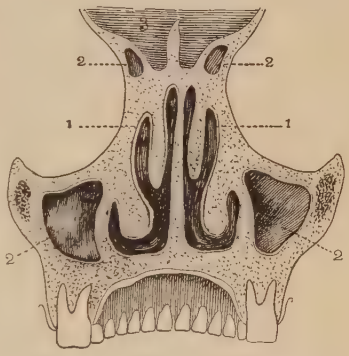

FIG. 53. — **Human air filter.** Diagram of a section through the nostrils; shows projecting bones covered with moist membrane against which the air is made to strike by the narrow passages. 1. Air passages. 2. Cavities in the bones, called sinuses. 3. Front lower portion of the cranial cavity.

Cultivate Full Breathing. — Many people, while apparently taking in enough air to supply their need for oxygen, do not breathe deeply enough to "freely ventilate the lungs." "Shallow breathing," as this is called, fails to keep up good local resistance of all the lung surfaces. While shallow breathing is dependent upon bad posture, lack of exercise, tight clothing around the chest or the waist, and too much indoor life, it is also dependent upon

habit. To overcome the habit, we should form the opposing habit by breathing deeply whenever we think of it. In addition to this, one may take deep-breathing exercises at stated intervals. Standing or sitting erect with chest up and chin slightly depressed, air is drawn through the nostrils until the lungs are *completely* full. After holding this long enough to count three slowly, it is quickly expelled. One should avoid straining, and if the lungs are weak, he should not inflate them to their full capacity. Deep breathing may also be combined with exercises for improving the bodily shape.[1]

Ventilation. — This is the general process by which air within an inclosed space, or room, is kept in a proper condition for health. According to our present knowledge there are four main conditions to be supplied by ventilation, as follows:

1. *Air of the right temperature* — from 68 to 70° F. in the winter or when artificial heat must be supplied.

2. *Air with the right movement* — barely enough to be felt by the skin or to make a candle flame flicker. Strong drafts must be avoided.

3. *Air with the right amount of moisture* — from 50 to 60% relative humidity.

4. *Air that is pure* — having enough oxygen and not too much carbon dioxid and free from poisonous gases and dust and smoke.

[1] The following exercise, from Dudley A. Sargent's *Health, Strength, and Power,* will be found most beneficial: "Stand with the feet together, face downward, arms extended downward, and backs of the hands touching. Raise the hands, arms, and elbows, keeping the backs of the hands together until they pass the chest and face. Then continue the movement upward, until the hands separate above the head with the face turned upward, when they should be brought downward and outward in a large circle to the starting point. Begin to inhale as the arms are raised and take in as much air as possible by the time the hands are above the head, then allow the breath to go out slowly as the arms descend."

Why these Conditions Are Necessary. — Air that is too hot keeps the body from getting rid of its heat as fast as it should and, on this account, retards our chemical changes. Air cold enough to chill the body wastes our heat and tends to congest the mucous linings. Air should have a slight movement to prevent rebreathing and to aid the body in keeping cool, and it must have a certain amount of moisture for the sake of the mucous linings and for its effect upon the regulation of temperature (p. 282). Air that is chemically and physically pure is better for the health in several ways. Generally speaking, air with the qualities named above is a constant aid to good local resistance of the lungs and air passages and to good general resistance.

FIG. 54. — **Window** adjusted for ventilation without drafts.

Suggestions on Ventilation. — Although the usual plan is to provide for ventilation through the construction of our buildings and the arrangements for heating, occasions are frequent when it is necessary to open windows and to make other adjustments in order to keep the indoor air in a proper condition. The one "ventilating" should:

1. Provide many small openings instead of a few large ones in order to get sufficient air without causing drafts (Fig. 54).

2. Introduce the air at the warmest portions of the room so that it may be warmed before reaching the occupants.

3. Ventilate principally on the sheltered side of the house when the wind is blowing.

4. Make ample provisions, by heating water in vessels, for sufficient moisture in the air.

Tobacco Smoke and the Air Passages. — Smoke consists of minute particles of unburnt carbon, or soot, such

as collect in the chimneys of fireplaces and furnaces. If much smoke is taken into the lungs, it irritates the delicate linings and tends to lower their resistance. Tobacco smoke also contains the poison nicotine which is absorbed into the blood. For these reasons the cigarette user who inhales the smoke does himself great harm. The practice of smoking indoors is likewise objectionable, since every one in the room is compelled to breathe the smoke.

FIG. 55. — **Artificial respiration** as a laboratory experiment. Expiration. Prone-posture method of Schaffer.

Artificial Respiration. — When natural breathing is temporarily suspended, as in partial drowning, or when one has been overcome by breathing some poisonous gas, the saving of life often depends upon the prompt application of artificial respiration. This is accomplished by alternately compressing and enlarging the thorax by means of variable pressure on the outside, imitating the natural process as nearly as possible. Following is the method proposed by Professor E. A. Schaffer of England, and called by him "the *prone-posture* method of artificial respiration":

The patient is laid face downward with an arm bent under the head, and *intermittent* pressure applied vertically over the shortest ribs. The pressure drives the air from the lungs, both by compressing the lower portions of the chest and by forcing the abdominal contents against the diaphragm, while the elastic reaction of the parts causes fresh air to enter (Figs. 55 and 56). "The operator kneels or squats

by the side of or across the patient, places his hands over the lowest ribs and swings his body backward and forward so as to allow his weight to fall vertically on the wrists and then to be removed; in this way hardly any muscular exertion is required. . . . The pressure is applied gradually and slowly, occupying some three seconds; it is then withdrawn during two seconds and again applied; and so on some twelve times per minute."

The special advantages of the prone-posture method over others that have been employed are: 1. It may be applied by a single individual and for a long period of time without exhaustion. 2. It allows the mucus and water (in case of drowning) to run out of the mouth, and causes the tongue to fall forward so as not to obstruct the passageway. 3. It brings a sufficient amount of air into the lungs.[1]

FIG. 56. — **Artificial respiration.** Inspiration.

Summary. — Right living aids constantly in keeping up good local resistance of the lungs and air passages and good general resistance of the body as a whole. Such living requires a proper attention to posture, to clothing and footwear, and to our methods of eating, sleeping, exercising, and breathing. Living rightly as regards these things and making a good fight against our little enemies,

[1] Testing the prone-posture method by suitable apparatus, Professor Schaffer has found it capable of introducing more air per minute into the lungs than any of the other methods of artificial respiration, and more even than is introduced by ordinary breathing.

the colds, we will keep up the second of our health foundations (p. 22) and avoid such health tragedies as pneumonia and tuberculosis.

Exercises. — 1. What is meant by the body's resistance? Distinguish between local resistance and general resistance.

2. Upon what does a good local resistance of the air passages depend? Upon what does good general resistance depend?

3. In what different ways may our methods of living impair the local resistance of the air passages?

4. What kinds of living improve the general resistance?

5. Why may we regard pneumonia and tuberculosis of the lungs as diseases of wrong living?

6. Discuss effects of clothing upon the lungs and air passages.

7. Why is the user of alcohol more apt to contract pneumonia than the non-user? Why is he less apt to recover?

8. Why are colds serious conditions? How is the cold to be managed? How is it to be avoided in the first place?

9. Give five reasons for breathing through the nose. Discuss methods by which this is accomplished.

10. Why is shallow breathing objectionable? How is it corrected?

11. What four conditions are supplied in a room properly ventilated? Why are they all necessary?

12. Name six or more habits that aid in keeping up our health foundation of normal breathing.

CHAPTER XII

FOODS AND THE THEORY OF DIGESTION

The body is constantly in need of new material. Oxidation, as shown in the preceding chapter, rapidly destroys substances at the cells, and these have to be replaced. Upon this renewal depends the supply of energy. Moreover, there is found to be an actual breaking down of the living material, or protoplasm, in the body. While this does not destroy the cells, as is sometimes erroneously stated, it reduces the quantity of the protoplasm and makes necessary a process of repair, or rebuilding, of the tissues. This also requires new material. Finally, substances, such as water and common salt, are required for the aid which they render in the general work of the body. Since these are constantly being lost in one way or another, they also must be replaced. These different needs of the body for new materials are supplied through

The Foods. — Foods are substances that, on being taken into the healthy body, are of assistance in carrying on its work. This definition properly includes oxygen, but the term is usually limited to substances introduced through the digestive organs. As suggested above, foods serve at least three purposes:

1. They, with oxygen, supply the body with energy.
2. They provide materials for rebuilding the tissues.
3. They supply materials that aid directly or indirectly in the general work of the body.

The Simple Foods, or Nutrients. — From the great variety of things that are eaten, it might appear that many different kinds of substances are suitable for food. When our various animal and vegetable foods are analyzed, however, they are found to be similar in composition and to contain only some five or six kinds of materials that are essentially different. While certain foods may contain only a single one of these, most of the foods are mixtures of two or more. These few common materials which, in different proportions, form the different things that are eaten, are variously referred to as simple foods, food-stuffs, and *nutrients*, the last name being the one generally preferred. The different classes of nutrients are as follows:

Nutrients
- Proteins and albuminoids
- Carbohydrates
- Fats
- Mineral salts
- Vitamines
- Water

It is now necessary to become somewhat familiar with the different nutrients and the purposes which they serve in the body.

Proteins.[1] — The proteins are obtained in part from the animal and in part from the plant kingdom, there being several varieties. A well-known variety, called *albumin*, is found in the white of eggs and in the plasma of the blood, while the muscles contain an abundance of another variety, known as *myosin*. Cheese consists largely of a kind of protein, called *casein*, which is also present in milk, but in a more diluted form. If a mouthful of wheat is chewed for some time, most of it is dissolved and swallowed, but there remains in the mouth a sticky, gum-like substance. This is *gluten*, a form of protein which occurs

[1] Also called proteids.

chiefly in wheat. Again, certain vegetables, as beans, peas, and peanuts, are rich in a kind of protein which is called *legumen*.

Proteins are compounds of carbon, hydrogen, oxygen, nitrogen, and a small per cent of sulphur. Certain ones (the nucleo-proteins from grains) also contain phosphorus. All of the proteins are highly complex compounds and form a most important class of nutrients.

Purposes of Proteins. — The chief purpose of proteins in the body is to rebuild the tissues. Not only do they supply all of the main elements in the tissues, but they are of such a nature chemically that they are readily built into the protoplasm. They are absolutely essential to life, no other nutrients being able to take their place. An animal deprived of them exhausts the proteins in its body and then dies. In addition to rebuilding the tissues, proteins may also be oxidized to supply the body with energy.

Albuminoids form a small class of foods, of minor importance, which are similar to proteins in composition, but differ from them in being unable to rebuild the tissues. Gelatin, a constituent of soup and obtained from bones and connective tissue by boiling, is the best known of the albuminoid foods. On account of the nitrogen which they contain, proteins and albuminoids are often classed together as *nitrogenous foods*.

Carbohydrates. — While the carbohydrates are not so essential to life as are the proteins, they are of very great value in the body. They are composed of carbon, hydrogen, and oxygen, and are obtained mainly from plants. There are several varieties of carbohydrates, but they are similar in composition. All of those used as food to any great extent are starch and certain kinds of sugar.

Starch is the carbohydrate of greatest importance as a food, and it is also the one found in the greatest abundance. All green plants form more or less starch, and many of them store it in their leaves, seeds, or roots (Fig. 57). From these sources it is obtained as food.

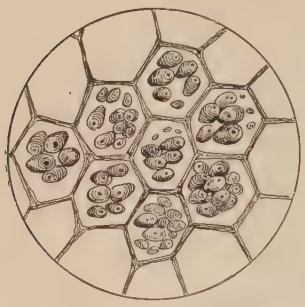

FIG. 57. — **Starch grains** in cells of potato as they appear under the microscope. (See practical work.)

Glycogen, a substance closely resembling starch, is found in the body of the oyster. It is also formed in the liver and muscles of the higher animals, being prepared from the sugar of the blood, and is stored by them as reserve food (Chapter XVI). Glycogen is, on this account, called *animal starch*. Starch on being eaten is first changed to sugar, after which it may be converted into glycogen in the liver and in the muscles.

Sugars. — There are several varieties of sugar, but the important ones used as foods fall into one or the other of two classes, known as *double sugars* (disaccharides) and *single sugars* (monosaccharides). To the first class belong *cane sugar*, found in sugar cane and beets, *milk sugar*, found in sweet milk, and *maltose*, a kind of sugar which is made from starch by the action of malt. The important members of the second class are *grape sugar*, or dextrose, and *fruit sugar*, or levulose, both of which are found in fruits and in honey.

The most important of all sugars, so far as its use in the body is concerned, is *dextrose*. To this form all the other sugars, and starch also, are converted before they are finally used in the body. The close chemical relation

between the different carbohydrates makes such a conversion easily possible.

Fats. — The fats used as foods belong to one or the other of two classes, known as solid fats and oils. The solid fats are derived chiefly from animals, and the oils are obtained mostly from plants. Butter, the fat of meats, olive oil, and the oil of nuts are the fats of greatest importance as foods. Fats, like the carbohydrates, are composed of carbon, hydrogen, and oxygen. They are rather complex chemical compounds, though not so complex as proteins. Since neither fats nor carbohydrates contain nitrogen, they are frequently classed together as *non-nitrogenous* foods.

Purpose Served by Carbohydrates, Fats, and Albuminoids. — These classes of nutrients all serve the common purpose of supplying energy. By uniting with oxygen at the cells, they supply heat and the other forms of bodily force. This is perhaps their only purpose.[1] Proteins also serve this purpose, but they are not so well adapted to supplying energy as are the carbohydrates and the fats. In the first place they do not completely oxidize and therefore do not supply so much energy; and, in the second place, they form waste products that are removed with difficulty from the body.

Mineral Salts and their Uses. — Mineral salts are found in small quantities in all of the more common food materials, and, as a rule, find their way into the body unnoticed. They supply the elements which are found in the body in small quantities and serve a variety of pur-

[1] While awaiting oxidation at the cells, the carbohydrates and fats are stored up by the body, the carbohydrates as glycogen and the fats as some form of fat. In this sense they are sometimes looked upon as serving to build up certain of the tissues.

poses. Calcium phosphate and calcium carbonate are important constituents of the bones and teeth; and the salts containing iron renew the hemoglobin of the blood. Others perform important functions in the vital processes. The mineral compound of greatest importance perhaps is sodium chloride, or common salt. This is a natural constituent of most of our foods, and is also added to food in its preparation for the table. When it is withheld from animals for a considerable length of time, they suffer intensely and finally die. It is necessary in the blood and lymph to keep their constituents in solution, and is thought to play an important rôle in the chemical changes of the cells. It is constantly leaving the body as a waste product and must be constantly supplied by our food.

Vitamines. — These are substances which occur in amounts so small as to defy chemical analysis and which were discovered through experiments in limiting the diets of animals to proteins, fats, carbohydrates, and mineral salts.[1] They are essential to life and growth and are of at least three kinds, as follows:

1. *Fat soluble A*, which is found in whole milk, butter, eggs, and the leafy parts of plants, and in the glands of animals.

2. *Water soluble B*, which is found in the germs of all kinds of seeds.

3. *Water soluble C*, which occurs widely in fruits and vegetables and is quite abundant in the juices of oranges, tomatoes, and other fruits, and also in milk. This vitamine is destroyed by heat.

Much credit is due modern investigators, chiefly American, for the discovery of this class of nutrients.

Importance of Water. — Water finds its way into the

[1] See McCollum's *The Newer Knowledge of Nutrition.*

body as a pure liquid, as a part of such mixtures as coffee, chocolate, and milk, and as a constituent of all our solid foods. (See table of foods, page 130.) It is also formed in the body by the oxidation of hydrogen. It passes through the body unchanged, and is constantly being removed by all the organs of excretion. Though water does not liberate energy in the body nor build up the tissues in the sense that other foods do, it is as necessary to the maintenance of life as oxygen or proteins. It occurs in all the tissues, and forms about 70 per cent of the entire weight of the body. Its presence is necessary for the interchange of materials at the cells and for keeping the tissues soft and pliable. As it enters the body, it carries digested food substances with it, and as it leaves it is loaded with wastes. Its chief physiological work, which is that of a *transporter of material*, depends upon its ability to dissolve substances and to flow readily from place to place.

Relative Quantity of Nutrients Needed. — Proteins, carbohydrates, and fats are the nutrients that supply most of the body's nourishment. The most hygienic diet is the one which supplies the proteins in sufficient quantity to rebuild the tissues, the carbohydrates and fats in the right amounts to supply the body with energy, and a sufficient variety of mineral salts and vitamines. Much experimenting has been done with a view to determining these proportions, but the results so far are not entirely satisfactory. According to some of the older estimates, a person of average size requires for his daily use five ounces of protein, two and one half ounces of fat, and fifteen ounces of carbohydrate. Recent investigations of this problem seem to show that the body is as well, if not better, nourished by a much smaller amount of protein — not more than two and one half ounces (60 grams) daily.[1]

[1] Chittenden, *The Nutrition of Man*.

While there is probably no necessity for the healthy individual's taking his protein, fat, and carbohydrate in *exact* proportions (if the proportions best suited to his body were known), the fact needs to be emphasized that proteins, although absolutely necessary, should form but a small part (not over one fifth) of the daily bill of fare. In recognition of this fact is involved a principle of health and also one of economy. The proteins, especially those in meats, are the most expensive of the nutrients, whereas the carbohydrates, which should form the greater bulk of one's food, are the least expensive.

Effects of a One-sided Diet. — The plan of the body is such as to require a *mixed diet*, and all of the great classes of nutrients are necessary. If one could subsist on any single class, it would be proteins, for proteins are able both to rebuild tissue and to supply energy. But if proteins are eaten much in excess of the body's need for rebuilding the tissues, and this excess is oxidized for supplying energy, a strain is thrown upon the organs of excretion, because of the increase in the wastes. Not only is there danger of overworking certain of these organs (the liver and kidneys), but the wastes may linger too long in the body, causing disorder and laying the foundation for disease. On the other hand, if an insufficient amount of protein is taken, the tissues are improperly nourished, and one is unable to exert his usual strength. What is true of the proteins is true, though in a different way, of the other great classes of foods. A diet which is lacking in protein, carbohydrate, fat, or other nutrients, or which has any one of them in excess, is not adapted to the requirements of the body.

Composition of the Food Materials. — One who intelligently provides the daily bill of fare must have some knowledge of the nature and quantity of the nutrients

present in the different materials used as food. This information is supplied by the chemist, who has made extensive analyses for this purpose. Results of such analyses are shown in Table 1 (page 130), which gives the percentage of proteins, fats, carbohydrates, water, and mineral salts in the edible portions of the more common of our foods.

Food Supply to the Table. — The main problem in supplying the daily bill of fare is that of securing through the

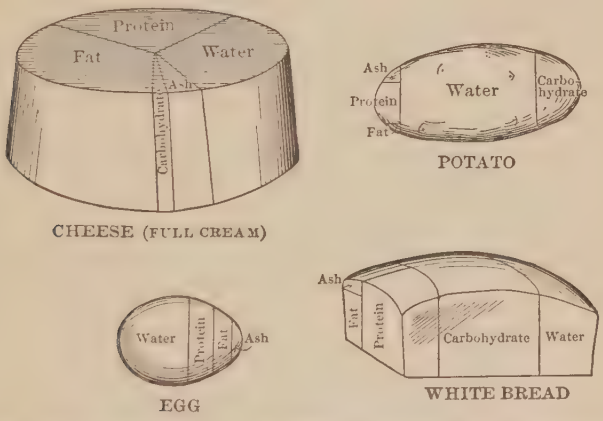

FIG. 58. — **Relative proportions of different nutrients in well-known foods.**

different food materials the requisite amounts of proteins, carbohydrates, and fats. In this matter a table showing the composition of foods can be used to great advantage. Consulting the table on page 130, it is seen that large per cents of proteins are supplied by lean meat, eggs, cheese, beans, peas, peanuts, and oatmeal, while fat is in excess in fat meat, butter, and nuts (Fig. 58). Carbohydrates are supplied in abundance by potatoes, rice, corn, sugar, and molasses. The different cereals also contain a large percentage of carbohydrates in the form of starch.

TABLE 1. THE COMPOSITION OF FOOD MATERIALS[1]

FOOD MATERIALS	WATER	SOLIDS	PROTEIN	FAT	CARBOHYDRATES	MINERAL MATTER	HEAT VALUE OF ONE POUND
Animal foods, edible portion	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Calories[2]
Beef: Shoulder	63.9	36.1	19.5	15.6	. . .	1	1020
Rib	48.1	51.9	15.4	35.6	. . .	.9	1790
Sirloin	60	40	18.5	20.5	. . .	1	1210
Round	68.2	31.8	20.5	10.1	. . .	1.2	805
Veal: Shoulder	68.8	31.2	20.2	9.8	. . .	. . .	790
Mutton: Leg	61.8	38.2	18.3	19	. . .	.9	1140
Loin	49.3	50.7	15	35	. . .	.7	1755
Pork: Shoulder	50.3	49.7	16	32.8	. . .	.9	1680
Ham, salted, smoked	41.5	58.5	16.7	39.1	. . .	2.7	1960
Fat, salted	12.1	87.9	.9	82.8	. . .	4.2	3510
Sausage: Pork	41.5	58.8	13.8	42.8	. . .	2.2	2065
Bologna	62.4	37.6	18.8	42.8	. . .	3	1015
Chicken	72.2	27.8	24.4	1	. . .	1.4	540
Eggs	73.8	26.2	14.9	10.5	. . .	.8	721
Milk	87	13	3.6	4	4.7	.7	325
Butter	10.5	89	.6	85	.5	.3	3515
Cheese: Full cream	30.2	69.8	28.3	35.5	1.8	4.2	2070
Skim milk	41.3	58.7	38.4	6.8	6.9	4.6	1165

	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Calories [2]
Fish: Codfish . .	82.6	17.4	15.8	.5	. . .	1 2	310
Salmon . .	63.6	36.4	21.6	13.4	. . .	1.4	965
Oysters . .	87 1	12.9	6	1.2	3.7	2	230
Vegetable foods							
Wheat flour . . .	12.5	87.5	11	1.1	74.9	.5	1645
Graham flour (wheat)	13.1	86.9	11.7	1.7	71.7	1.8	1635
Rye flour	13.1	86.9	6.7	.8	78.7	.7	1625
Buckwheat flour . .	14.6	85.4	6 9	1.4	76.1	1	1605
Oatmeal	7.6	92.4	15.1	7.1	68.2	2	1850
Cornmeal	15	85	9.2	3.8	70.6	1.4	1645
Rice	12.4	87.6	7.4	.4	79.4	.4	1630
Peas	12.3	87.7	26.7	1.7	56.4	2.9	1565
Beans	12.6	87.4	23 1	2	59.2	3.1	1615
Potatoes	78.9	21.1	2.1	.1	17.9	1	375
Tomatoes	95.3	4.7	.8	.4	3.2	.3	80
Apples	83.2	16.8	.2	.4	15.9	.3	315
Sugar, granulated .	2	98	. .	. .	97.8	.3	1820
White bread (wheat)	32.3	67.7	8.2	1.7	56.3	.0	1280
Peanuts	9 2	90.8	25.8	24.4	38.6	2	2560
Almonds	4.8	95.2	21	17.3	54.9	2	3030
Walnuts (English) .	2.5	97.5	16.6	16.1	63.4	1.4	3285

[1] Compiled from different sources, but mainly from Atwater's *Foods: Nutritive Value and Cost*, published by the U. S. Department ot Agriculture.

[2] The calorie is the adopted heat unit. As used in this table it may be defined as the quantity of heat required to raise 1 kilogram (2.2 pounds) of water, 1 degree centigrade. The calories also show the relative amount of energy supplied by the different foods.

The Properly Planned Menu. — This is a menu that makes it possible for those partaking of it to satisfy all of their needs and to do so without undue waste of food materials. There should be supplied to the table at each meal, one dish rich in protein, one or more dishes rich in starch, one rich in sugar, and one rich in fat, in addition to some harmless drink, such as water. There should also be supplied some fruit or vegetable for the sake of the mineral salts that they contain, and either milk, butter, the leafy parts of plants, or fresh oranges or tomatoes for their vitamines.

Balancing Rule for the Eater. — The most carefully planned menu will be spoiled if the eater does not have some practical plan for eating what he needs in the right proportions. A rule sufficiently definite for practical purposes is the following: At each meal, eat a small serving of one food rich in protein, a small serving of one food rich in fat, rather liberal servings of two foods rich in carbohydrates, one rich in starch, and the other rich in sugar, and at different meals, eat a variety of fruits and vegetables to supply mineral salts. To supply vitamines, one should have at different meals a variable amount of whole milk, butter, the leafy parts of plants, and raw tomatoes, oranges, or other fruits.

The Need for Variety. — One should have variety in his proteins because the different kinds are not exactly the same in composition. But mineral salts are needed in greater variety than proteins, and these are by no means the same in different fruits and vegetables. Supplying variety, however, should not increase either the work or the expense of preparing meals. These are avoided by having each meal simple in itself, but differing in important respects from the meal preceding and the one following.

Alcohol not a Food. — Recently it has been shown that alcohol when introduced into the body in small quantities is nearly all oxidized, yielding energy as does fat or sugar. If no harmful effects attended the use of alcohol, it might on this account be classed as a food. But alcohol is known to be harmful to the body. When used in large quantities, it injures nearly all of the tissues, and when taken habitually, even in small doses, it leads to the formation of the alcohol habit which is now recognized and treated as a disease. This and other facts show that alcohol is not adapted to the body plan of taking on and using new material (Chapter XVI), and no substance lacking in this respect can properly be classed as a food.[1] Instead of classing alcohol as a food, it should be placed in that long list of substances which are introduced into the body for special purposes and which are known by the general name of

Drugs. — Drugs act strongly upon the body and tend to bring about unusual and unnatural results. Their use should in no way be confused with that of foods. If taken in health, they tend to disturb the physiological balance of the body by unduly increasing or diminishing the action of the different organs. In disease where this balance is already disturbed, they may be administered for their counteractive effects, but always under the advice and direction of a physician. Knowing the nature of the disturbance which the drug produces, the physician can administer it to advantage, should the body be out of physiological

[1] While alcohol cannot be classed as a food, it is believed by some authorities to contain *food value* and, in the hands of the physician, to be a substance capable of rendering an actual service in the treatment of certain diseases. It might, for example, be used where one's power of digestion is greatly impaired, since alcohol requires no digestion. But upon this point there is a decided difference of opinion. Certain it is that no one should attempt to use alcohol as food or medicine except under the advice and direction of his physician.

balance, or diseased. Not only are drugs of no value in health, but their use is liable to do much harm.

NATURE OF DIGESTION

Before the nutrients can be oxidized at the cells, or built into the protoplasm, they undergo a number of changes. These are necessary for their entrance into the body, for their distribution by the blood and the lymph, and for the purposes which they finally serve. The first of these changes is preparatory to the entrance of the nutrients and is known as *digestion*. The organs which bring about this change, called digestive organs, have a special construction which adapts them to their work. It will assist materially in understanding these organs if we first learn something of the nature of the work which they have to perform.

How the Nutrients get into the Body. — The nature of digestion is determined by the conditions affecting the entrance of nutrients into the body. Food in the stomach and air in the lungs, although surrounded by the body, are still outside of what is called the *body proper*. To gain entrance into the body proper, a substance must pass through the body wall. This consists of the skin on the outside and of the mucous linings of the air passages and other tubes and cavities which are connected with the external surface.

To get from the digestive organs into the blood, the nutrients must pass through the mucous membrane lining these organs and also the walls of blood or lymph vessels. Only *liquid materials* can make this passage. It is necessary, therefore, to reduce to the liquid state all nutrients not already in that condition. *This reduction to the liquid state constitutes the digestive process.*

How Substances are Liquefied. — While the reduction of solids to the liquid state is accomplished in some instances by heating them until they melt, they are more frequently reduced to this state by subjecting them to the action of certain liquids, called *solvents*. Through the action of the solvent the minute particles of the solid separate from each other and disappear from view. (Shown in dropping salt in water.) At the same time they mix with the solvent, forming a *solution*, from which they separate only with great difficulty. For this reason solids in solution can pass through porous partitions along with the solvents in which they are dissolved.

By digestion the nutrients are reduced to the form of a solution. *The process is*, simply speaking, *one of dissolving*. The liquid employed as *the digestive solvent is water*. The different nutrients dissolve in water, mixing with it to form a solution which is then passed into the body proper.

Digestion not a Simple Process. — Digestion is by no means a simple process, such, for instance, as the dissolving of salt or sugar in water. These, being soluble in water, dissolve at once on being mixed with a sufficient amount of this liquid. The majority of the nutrients, however, are insoluble in water and are unaffected by it when acting alone. Fats, starch, and most of the proteins do not dissolve in water. Before these can be dissolved they have to be changed chemically and converted into substances that are *soluble in water*. This complicates the process and *prevents the use of water alone* as the digestive solvent.

A Similar Case. — If a piece of limestone be placed in water, it does not dissolve, because it is insoluble in water. If hydrochloric acid is now added to the water, the lime-

stone is very soon completely dissolved (Fig. 59). It seems at first thought that the acid dissolves the limestone, but this is not the case. The acid produces a chemical change in the limestone (calcium carbonate) and converts it into a compound (calcium chloride) that is soluble in water. As fast as this is formed it is dissolved by the water, which is the real solvent in the case. The acid simply plays the part of a chemical converter.

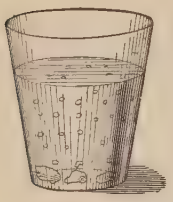

FIG. 59. — **The dissolving of limestone** in water containing acid, suggesting the double action in the digestion of most foods.

The Digestive Fluids. — Several fluids — saliva, gastric juice, pancreatic juice, bile, and intestinal juice — are employed in the digestion of the food. The composition of these fluids is in keeping with the nature of the digestive process. While all of them have water for their most abundant constituent, there are dissolved in the water small amounts of active chemical agents. It is the work of these agents to convert the insoluble nutrients into substances that are soluble in water. The digestive fluids are thus able to act in a *double* manner on the nutrients — to change them chemically and to dissolve them. The chemical agents which bring about the changes in the nutrients are called *enzymes*, or digestive ferments.

Foods Classed with Reference to Digestive Changes. — With reference to the changes which they undergo during digestion, foods may be divided into three classes as follows:

1. Substances already in the liquid state and requiring no digestive action. Water and solutions of simple foods in water belong to this class. Milk and liquid fats, or oils, do not belong to this class.

2. Solid foods soluble in water. This class includes

common salt and sugar. These require no digestive action other than dissolving in water.

3. Foods that are insoluble in water. These have first to be changed into soluble substances, after which they are dissolved.

Summary. — Materials called foods are introduced into the body for rebuilding the tissues, supplying energy, and aiding in its general work. Only a few classes of substances, viz., proteins, carbohydrates, fats, mineral salts, vitamines, and water, have all the qualities of foods and are suitable for introduction into the body. These are obtained from different food materials and should be eaten in sufficient amounts and properly balanced. Before foods can be passed into the body proper, they must be converted into the liquid form, or dissolved. This process is known as digestion.

Exercises. — 1. How does oxidation at the cells make necessary the introduction of new materials into the body?

2. What different purposes are served by the foods?

3. What is a nutrient? Name the important classes.

4. What are food materials? From what sources are they obtained?

5. Name the different kinds of proteins; the different kinds of carbohydrates. What are vitamines?

6. Show why life cannot be carried on without proteins; without water.

7. What per cents of protein, fat, and carbohydrate are found in wheat flour, oatmeal, rice, butter, potatoes, round beef, eggs, and peanuts?

8. State the objection to a meal consisting of beef, eggs, beans, bread, and butter; to one consisting of potatoes, rice, bread, and butter. Which is the more objectionable of these meals and why?

9. State the general plan of digestion.

10. Show that digestion is not a simple process like that of dissolving salt in water.

CHAPTER XIII

ORGANS AND PROCESSES OF DIGESTION

The organs of digestion are adapted to the work of dissolving the foods by both their structure and arrangement. Most of them consist either of tubes or cavities and these are so connected, one with the other, as to form a continuous passageway entirely through the body. This passageway is known as

The Alimentary Canal. — The alimentary canal has a length of about thirty feet and, while it begins at the mouth, all but about eighteen inches of it is found in the abdominal cavity. On account of its length it lies for the most part in coils, the two largest ones being known as the small intestine and the large intestine. Connected with the alimentary canal are the glands that supply the liquids for acting on the food. The divisions of the canal and most of the glands that empty liquids into it are shown in Fig. 60 and named in the table below:

- Digestive Organs
  - Parts of Alimentary Canal
    - Mouth, containing teeth and tongue
    - Pharynx
    - Esophagus
    - Stomach
    - Intestines
      - Small
        - Duodenum
        - Jejunum
        - Ileum
      - Large
        - Cæcum and vermiform appendix
        - Colon
          - Ascending
          - Transverse
          - Descending
          - Sigmoid flexure
        - Rectum
  - Digestive Glands
    - Salivary
      - Parotid
      - Submaxillary
      - Sublingual
    - Gastric
    - Liver
    - Pancreas
    - Intestinal

Coats of the Alimentary Canal. — The walls of the alimentary canal, except at the mouth, are distinct from the surrounding tissues and consist in most places of at least three layers, or coats, as follows:

1. An *inner coat*, or lining, known as the mucous membrane. This membrane is not confined to the alimentary canal, but lines, as we have seen, the different air passages. It covers, in fact, all those internal surfaces of the body that connect with the external surface. It derives its name from the substance which it secretes, called *mucus*. In structure it resembles the skin, being continuous with the skin where cavities open to the surface. It is made up of two layers — a thick underlayer which contains blood vessels, nerves, and glands, and a thin surface layer, called the *epithelium*. The epithelium, like the cuticle, is without blood vessels, nerves, or glands.

2. A *middle coat*, which is muscular and which forms a continuous layer throughout the canal, except at the mouth. (Here its place is taken by the strong muscles of mastication which are separate and distinct from each other.) As a

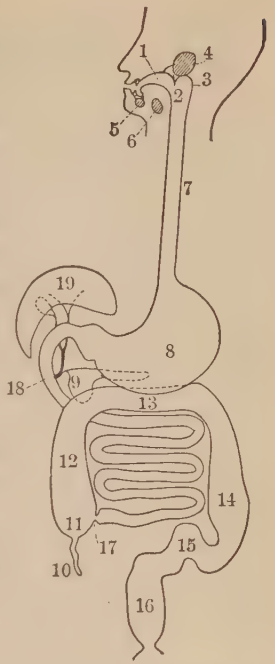

FIG. 60. — **Diagram of the digestive system.** 1. Mouth. 2. Soft palate. 3. Pharynx. 4. Parotid gland. 5. Sublingual gland. 6. Submaxillary gland. 7. Esophagus. 8. Stomach. 9. Pancreas. 10. Vermiform appendix. 11. Cæcum. 12. Ascending colon. 13. Transverse colon. 14. Descending colon. 15. Sigmoid flexure. 16. Rectum. 17. Ileocæcal valve. 18. Duct from liver and pancreas. 19. Liver.

Diagram does not show comparative length of the small intestine.

rule the muscles of this coat are involuntary. They surround the canal as thin sheets and at most places form two distinct layers. In the inner layer the fibers encircle the canal, but in the outer layer they run longitudinally, or lengthwise, along the canal.[1]

3. An *outer* or *serous coat*, which is limited to those portions of the canal that occupy the abdominal cavity. This coat is not found above the diaphragm. It is a part of the lining membrane of the cavity of the abdomen, called

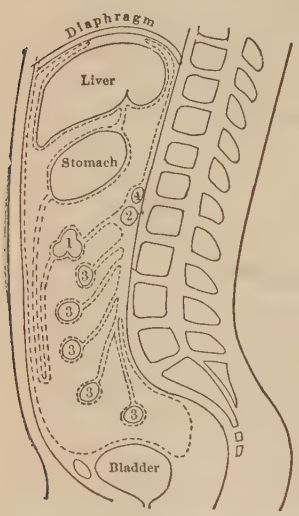

FIG. 61. — **Diagram of the peritoneum.** 1. Transverse colon. 2. Duodenum. 3. Small intestine. 4. Pancreas.

The Peritoneum. — The peritoneum is to the abdominal cavity what the pleura is to the thoracic cavity. It forms the outer covering for the alimentary canal and other abdominal organs and supplies the inner lining of the cavity itself. It is also the means of holding these organs in place, some of them being suspended by it from the abdominal walls (Fig. 61). By the secretion of a small amount of liquid, it prevents friction of the parts upon one another.

Digestive Glands. — The glands which provide the different fluids for acting on the foods derive their constituents from the blood. They are situated either in the mucous membrane or at convenient places outside of the

[1] A layer of connective tissue between the mucous membrane and the muscular coat is usually referred to as the *submucous* coat. This contains numerous blood vessels and nerves and binds the muscular coat to the mucous membrane.

canal and pass their liquids into it by means of small tubes, called ducts. In the canal the food and the digestive fluids come in direct contact — a condition which the dissolving processes require. Each kind of fluid is secreted by a special kind of gland and is emptied into the canal at the place where it is needed.

The Digestive Processes. — Digestion is accomplished by acting upon the food in different ways, as it is passed along the canal, with the final result of reducing it to the form of a solution. Several distinct processes are necessary and they occur in such an order that those preceding are preparatory to those that follow. These processes are known as *mastication*, *insalivation*, *deglutition*, *stomach digestion*, and *intestinal* digestion. As the different materials become liquefied they are transferred to the blood, and substances not reduced to the liquid state are passed on through the canal as waste. The first two of the digestive processes occur in

The Mouth. — This is an oval-shaped cavity situated at the very beginning of the canal. It is surrounded by the lips in front, by the cheeks on the sides, by the hard palate above and the soft palate behind, and by the tissues of the lower jaw below. The mucous membrane lining the mouth is soft and smooth, being covered with flat epithelial cells. The external opening of the mouth is guarded by the lips, and the soft palate forms a *movable* partition between the mouth and the pharynx. In a condition of repose the mouth space is practically filled by the teeth and the tongue, but the cavity may be enlarged and room provided for food by depressing the lower jaw.

The mouth by its construction is well adapted to carrying on the processes of mastication and insalivation. By the first process the solid food is reduced, by the cutting

and grinding action of the teeth, to a finely divided condition. By the second, the saliva becomes mixed with the food and is made to act upon it.

Accessory Organs of the Mouth.—The work of mastication and insalivation is accomplished through organs situated in and around the mouth cavity. These comprise:

1. *The Teeth.*—The teeth are set in the upper and lower jaws, one row directly over the other, with their hardened surfaces facing. In reducing the food, the teeth of the lower jaw move against those of the upper, while the food is held by the tongue and cheeks between the grinding surfaces. The front teeth are thin and chisel-shaped. They do not meet so squarely as do the back ones, but their edges glide over each other, like the blades of scissors—a condition that adapts them to cutting off and separating the food (*D*, Fig. 62). The back teeth are broad and irregular, having surfaces that are adapted to crushing and grinding.

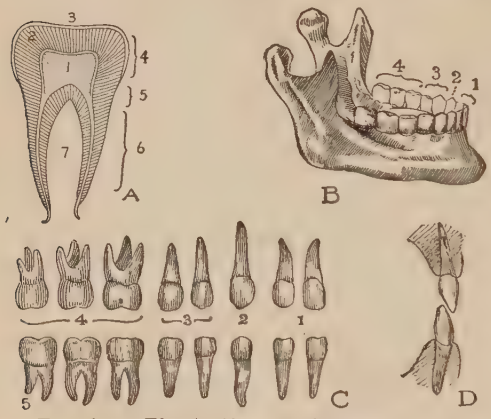

FIG. 62.—**The teeth.** *A*. Section of a molar. 1. Pulp. 2. Dentine. 3. Enamel. 4. Crown. 5. Neck. 6. Root cement. *B*. Teeth in position in lower jaw. 1. Incisors. 2. Canine. 3. Biscuspids. 4. Molars. *C*. Upper and lower teeth on one side. 1. Incisors. 2. Canines. 3. Bicuspids. 4. Molars. 5. Wisdom. *D*. Upper and lower incisor, to show gliding contact.

Each tooth is composed mainly of a bone-like substance, called *dentine*, which surrounds a central space, containing blood vessels and

nerves, known as the *pulp cavity*. It is set in a depression in the jaw where it is held firmly in place by a bony substance, known as *cement*. The part of the tooth exposed above the gum is the *crown*, the part surrounded by the gum is the *neck*, and the part which penetrates into the jaw is the *root* (*A*, Fig. 62). A hard, protective material, called *enamel*, covers the exposed surface of the tooth.

The teeth which first appear are known as the *temporary*, or milk, teeth and are twenty in number, ten in each jaw. They usually begin to appear about the sixth month, and they disappear from the mouth at intervals from the sixth to the thirteenth year. As they leave, teeth of the second, or *permanent*, set take their place. This set has thirty-two teeth of four different kinds arranged in the two jaws as follows:

In front, above and below, are four chisel-shaped teeth, known as the *incisors*. Next to these on either side is a tooth longer and thicker than the incisors, called the *canine*. Back of these are two short, rounded and double pointed teeth, the *bicuspids*, and back of the bicuspids are three heavy teeth with irregular grinding surfaces, called the *molars* (*B* and *C*, Fig. 65). Since the molar farthest back in each jaw is usually not cut until maturity, it is called a *wisdom* tooth. The molars are known as the superadded permanent teeth because they do not take the place of milk teeth, but form farther back as the jaw grows in length.

FIG. 63.—**Diagram** showing directions of muscular fibers in tongue.

2. *The Tongue.*—The tongue is a muscular organ whose fibers extend through it in several directions (Fig. 63). Its structure adapts it to a variety of movements. During mastication the tongue transfers the food from one part of the mouth to another, and, with the aid of the cheeks, holds the food between the rows of teeth. (By an outward pressure from the tongue and an inward pressure from the cheek the food is kept between the grinding surfaces.) The tongue has functions in addition to these and is a most useful organ.

3. *The Muscles of Mastication.*—These are attached to the lower jaw and bring about its different movements. The *masseter* muscles, which are the heavy muscles in the cheeks, and the *temporal* muscles, located in the region of the temples, raise the lower jaw and supply the force for grinding the food. Small muscles situated below the chin depress the jaw and open the mouth.

4. *The Salivary Glands.*—These glands are situated in the tissues surrounding the mouth, and communicate with it by means of ducts (Fig. 64). They secrete the saliva. The salivary glands are six in number and are arranged in three pairs. The largest, called the *parotid* glands, lie, one on either side, in front of and below the ears. A duct from each gland passes forward along the cheek until it opens in the interior of the mouth, opposite the second molar tooth in the upper jaw. Next in size to the parotids are the *submaxillary* glands. These are located, one on either side, just below and in front of the triangular bend in the lower jaw. The smallest of the salivary glands are the *sublingual*. They are situated in the floor of the mouth, on either side, at the front and base of the tongue. Ducts from the submaxillary and sublingual glands open into the mouth below the tip of the tongue.

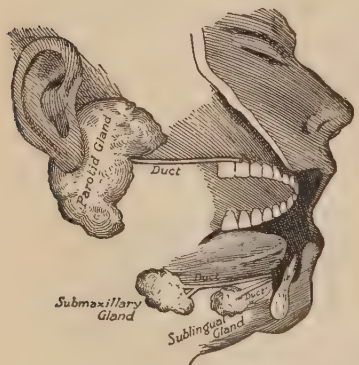

FIG. 64.—**Salivary glands** and the ducts connecting them with the mouth.

The Saliva and its Uses.—The saliva is a transparent and somewhat slimy liquid which is slightly alkaline. It

consists chiefly of water (about 99 per cent), but in this are dissolved certain salts and an active chemical agent, or enzyme, called *ptyalin*, which acts on the starch. The ptyalin changes starch into a form of sugar (maltose), while the water in the saliva dissolves the soluble portions of the food. In addition to this the saliva moistens and lubricates the food which it does not dissolve, and prepares it in this way for its passage to the stomach. The last is considered the most important use of the saliva, and dry substances, such as crackers, which require a considerable amount of this liquid, cannot be eaten rapidly without choking. Slow mastication favors the secretion and action of the saliva.

Deglutition. — Deglutition, or swallowing, is the process by which food is transferred from the mouth to the stomach. Though this is not, strictly speaking, a digestive process, it is, nevertheless, necessary for the further digestion of the food. Mastication and insalivation, which are largely mechanical, prepare the food for certain chemical processes by which it is dissolved. The first of these occurs in the stomach and to this organ the food is transferred from the mouth. The chief organs concerned in deglutition are the tongue, the pharynx, and the esophagus.

The Pharynx is a round and somewhat cone-shaped cavity, about four and one half inches in length, which lies just back of the nostrils, mouth, and larynx. It is remarkable for its openings, seven in number, by means of which it communicates with other cavities and tubes of the body. One of these openings is into the mouth, one into the esophagus, one into the larynx, and one into each of the nostrils, while two small tubes (the eustachian) pass from the upper part of the pharynx to the middle ears.

The pharynx is the part of the food canal that is crossed

by the passageway for the air. To keep the food from passing out of its natural channel, the openings into the air passages have to be carefully guarded. This is accomplished through the soft palate and epiglottis, which are operated somewhat as valves. The muscular coat of the pharynx is made up of a series of overlapping muscles which, by their contractions, draw the sides together and diminish the cavity. The mucous membrane lining the pharynx is smooth, like that of the mouth, being covered with a layer of flat epithelial cells.

The Esophagus, or gullet, is a tube eight or nine inches long, connecting the pharynx with the stomach. It lies for the most part in the thoracic cavity and consists chiefly of a thick mucous lining surrounded by a heavy coat of muscle. The muscular coat is composed of two layers — an inner layer whose fibers encircle the tube and an outer layer whose fibers run lengthwise.

Steps in Deglutition. — The process of deglutition varies with the kind of food. With bulky food it consists of three steps, or stages, as follows: 1. By the contraction of the muscles of the cheeks, the food ball, or bolus, is pressed into the center of the mouth and upon the upper surface of the tongue. Then the tongue, by an upward and backward movement, pushes the food under the soft palate and into the pharynx.

2. As the food passes from the mouth, the pharynx is drawn up to receive it. At the same time the soft palate is pushed upward and backward, closing the opening into the upper pharynx, while the epiglottis is made to close the opening into the larynx. By this means all communication between the food canal and the air passages is temporarily closed. The upper muscles of the pharynx now contract upon the food, forcing it downward and into the esophagus.

3. In the esophagus the food is forced along by the successive contractions of muscles, starting at the upper end of the tube, until the stomach is reached.

Swallowing is doubtless aided to some extent by the force of gravity.

That it is independent of this force, however, is shown by the fact that one may swallow with the esophagus in a horizontal position, as in lying down.

The Stomach. — The stomach is the largest dilatation of the alimentary canal. It is situated in the abdominal cavity, immediately below the diaphragm, with the larger portion toward the left side. Its connection with the esophagus is known as the *cardiac orifice* and its opening into the small intestine is called the *pyloric orifice*. It varies greatly in size in different individuals, being on the average from ten to twelve inches at its greatest length, from four to five inches at its greatest width, and holding from three to five pints. It has the coats common to the canal, but these are modified somewhat to adapt them to its work.

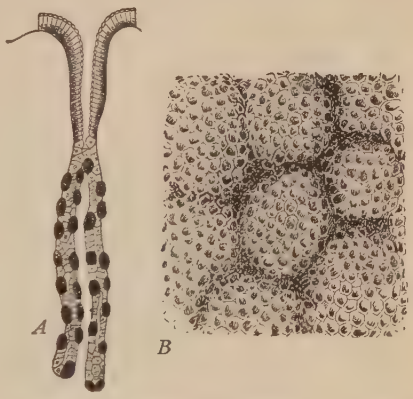

FIG. 65. — **Gastric Glands.** *A.* Single gland showing the two kinds of secreting cells and the duct where the gland opens on to the surface. *B.* Inner surface of stomach magnified. The small pits are the openings from the glands.

The mucous membrane of the stomach is thick and highly developed. It contains great numbers of minute tube-shaped bodies, known as the *gastric glands* (Fig. 65). These are of two general kinds and secrete large quantities of a liquid called the gastric juice. When the stomach is empty, the mucous membrane is thrown into folds which run lengthwise over the inner surface. These disappear, however, when the walls of the stomach are distended with food.

The muscular coat consists of *three* separate layers which are named, from the direction of the fibers, the circular layer, the longitudinal layer, and the oblique layer (Fig. 66).

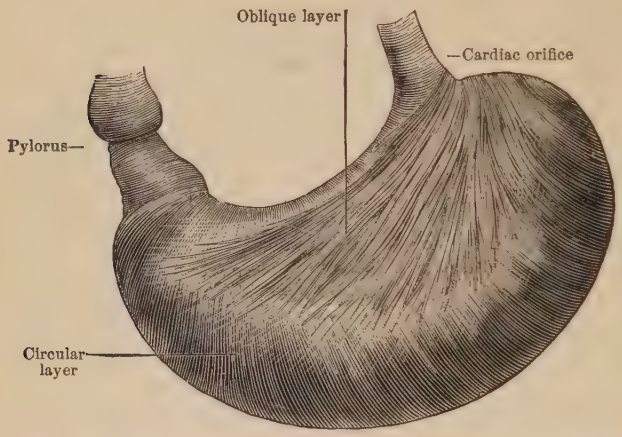

FIG. 66. — **Muscles of the stomach** (from Morris' *Human Anatomy*). The layer of longitudinal fibers removed.

The circular layer becomes quite thick at the pyloric orifice, forming a distinct band which serves as a valve.

The outer coat of the stomach, called the *serous coat*, is a continuation of the peritoneum, the membrane lining the abdominal cavity.

Stomach Digestion. — In the stomach begins the definite work of dissolving those foods which are insoluble in water. This, as already stated, is a double process. There is first a chemical action in which the insoluble are changed into soluble substances, and this is followed immediately by the dissolving action of water. The chief substances digested in the stomach are the proteins. These, in dissolving, are changed into two soluble substances, known as

peptones and *proteoses*. The digestion of the proteins is, of course, due to the

Gastric Juice. — The gastric juice is a thin, colorless liquid composed of about 99 per cent of water and about 1 per cent of other substances. The latter are dissolved in the water and include, besides several salts, three active chemical agents — hydrochloric acid, pepsin, and rennin. *Pepsin* is the enzyme which acts upon proteins, but it is able to act only in an acid medium — a condition which is supplied by the *hydrochloric acid*. Mixed with the hydrochloric acid it converts the proteins into peptones and proteoses.

Other Effects of the Gastric Juice. — In addition to digesting proteins, the gastric juice brings about several minor effects, as follows:

1. It checks, after a time, the digestion of the starch which was begun in the mouth by the saliva.[1] This is due to the presence of the hydrochloric acid, the ptyalin being unable to act in an acid medium.

2. While there is no appreciable action on the fat itself, the protein layers that inclose the fat particles are dissolved away (Fig. 79), and the fat is set free. By this means the fat is broken up and prepared for a special digestive action in the small intestine.

3. Dissolved albumin, like that in milk, is curded, or coagulated, in the stomach. This action is due to the *rennin*. The curded mass is then acted upon by the pepsin and hydrochloric acid in the same manner as the other proteins.

[1] The saliva may continue to act for a considerable time after the food enters the stomach. "Careful examination of the contents of the fundus (large end of the stomach) by Cannon and Day has shown that no inconsiderable amount of salivary digestion occurs in the stomach." — FISCHER, *The Physiology of Alimentation*.

4. The hydrochloric acid acts on certain of the insoluble mineral salts found in the foods and reduces them to a soluble condition.

5. It is also the opinion of certain physiologists that cane sugar and maltose (double sugars) are converted by the hydrochloric acid into dextrose and levulose (single sugars).

After a variable length of time, the contents of the stomach is reduced to a rather uniform and pulpy mass which is called *chyme*. Portions of this are now passed at intervals into the small intestine.

Muscular Action of the Stomach. — The muscles in the walls of the stomach have for one of their functions the mixing of the food with the gastric juice. By *alternately* contracting and relaxing, the different layers of muscle keep the form of the stomach changing — a result which agitates and mixes its contents. This action varies in different parts of the organ, being slight or entirely absent at the cardiac end, but quite marked at the pyloric end.

Another purpose of the muscular coat is to empty the stomach into the small intestine. During the greater part of the digestive period the muscular band at the pyloric orifice is contracted. At intervals, however, this band relaxes, permitting a part of the contents of the stomach to be forced into the small intestine. After the discharge the pyloric muscle again contracts, and so remains until the time arrives for another discharge.

In addition to emptying the stomach into the small intestine, these muscles also aid in emptying the organ upward and through the esophagus and mouth, should occasion require. Vomiting in case of poisoning, or if the food for some reason fails to digest, is a necessary though unpleasant operation. It is accomplished by the

contraction of all the muscles of the stomach, together with the contraction of the walls of the abdomen. During these contractions the pyloric valve is closed, and the muscles of the esophagus and pharynx are in a relaxed condition.[1]

The Small Intestine. — This division of the alimentary canal consists of a coiled tube, about twenty-two feet in length, which occupies the central, lower portion of the abdominal cavity (Fig. 68). At its upper extremity it connects with the pyloric end of the stomach (Fig. 67), and at its lower end it joins the large intestine. It averages a little over an inch in diameter, and gradually diminishes in size from the stomach to the large intestine. The first eight or ten inches form a short curve, known as the *duodenum*. The upper two fifths of the remainder is called the *jejunum*, and the lower three fifths is known as the *ileum*. The ileum joins that part of the large intestine known as the cæcum, and at their place of union is a marked constriction which prevents material from passing from the large into the small intestine (Fig. 70). This is known as the *ileo-cæcal valve*.

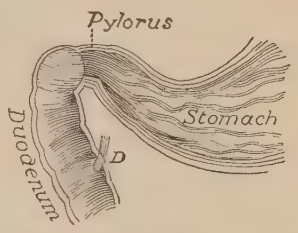

FIG. 67. — **Passage from stomach** into small intestine. Illustration also shows arrangement of mucous membrane in the two organs. *D.* Bile duct.

The mucous membrane of the small intestine is richly supplied with blood vessels and contains glands that secrete

[1] Perhaps the simplest method of inducing vomiting is that of thrusting a finger down the throat. To make this method effective the finger should be held in the throat until the vomiting begins. An emetic, such as a glass of lukewarm salt water containing a teaspoonful of mustard, should also be taken, and, in the case of having swallowed poison, the vomiting should be repeated several times. It may even be advantageous to drink water and then vomit it up in order to wash out the stomach.

a digestive fluid known as the *intestinal juice*. The membrane is thrown into many transverse, or circular, folds which increase its surface and also prevent materials from passing too rapidly through the intestine. One important respect in which the small intestine differs from all other portions of the food canal is that its surface is covered with great numbers of minute elevations known as the villi. The purpose of these is to aid in the absorption of the nutrients as they become dissolved.

The muscular coat of the small intestine is made up of two distinct layers — the inner layer consisting of circular fibers and the outer of longitudinal fibers. These muscles keep the food materials mixed with the juices of the small intestine, but their main purpose is to force the materials undergoing digestion through this long and much-coiled tube.

The outer, or *serous*, coat of the small intestine, like that of the stomach, is an extension from the general lining of the abdominal cavity, or peritoneum. In fact, the intestine lies in a fold of the peritoneum, somewhat as an arm in a sling, while the peritoneum, by connecting with the back wall of the abdominal cavity, holds this great coil of digestive tubing in place (Fig. 61). The portion of the peritoneum which attaches the intestine to the wall of the abdomen is called the *mesentery*.

Most of the liquid acting on the food in the small intestine is supplied by two large glands, the liver and the pancreas, that connect with it by ducts.

The Liver is situated immediately below the diaphragm, on the right side (Figs. 68 and 69), and is the largest gland in the body. It weighs about four pounds and is separated into two main divisions, or lobes. It is complex in structure and differs from the other glands in several particulars. It receives blood from two distinct sources — the portal vein

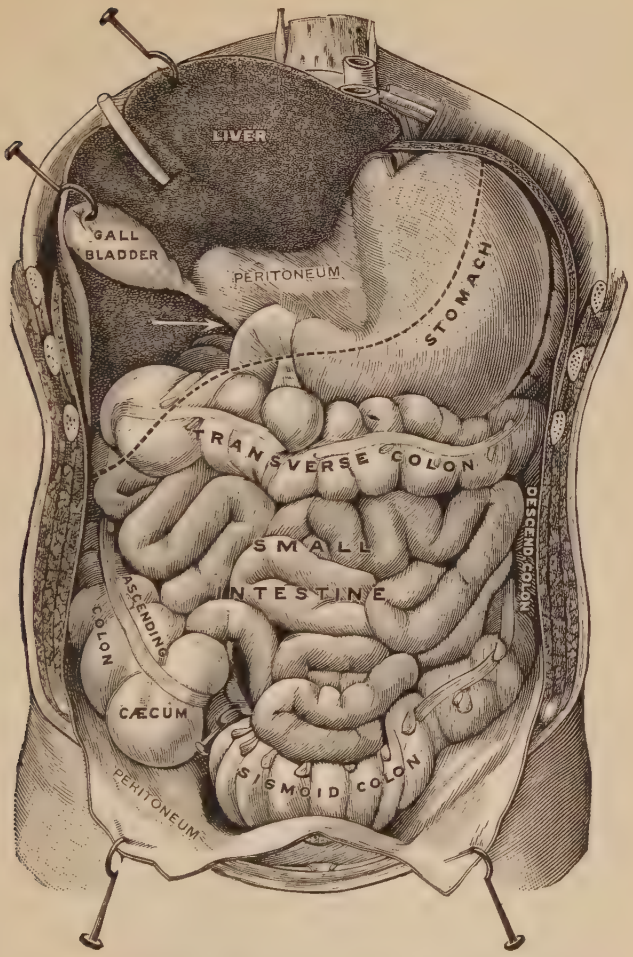

FIG. 68. — **Abdominal cavity** with organs of digestion in position.

and the hepatic artery. The *portal vein* collects the blood from the stomach, intestines, and spleen, and passes it to the liver. This blood is loaded with food materials, but contains little or no oxygen. The *hepatic artery*, which branches from the aorta, carries to the liver blood rich in oxygen. In the liver the portal vein and the hepatic artery divide and subdivide, and finally empty their blood into a single system of capillaries surrounding the liver cells. These capillaries in turn empty into a single system of veins which, uniting to form the *hepatic veins* (two or three in number), pass the blood into the inferior vena cava (Fig. 69).

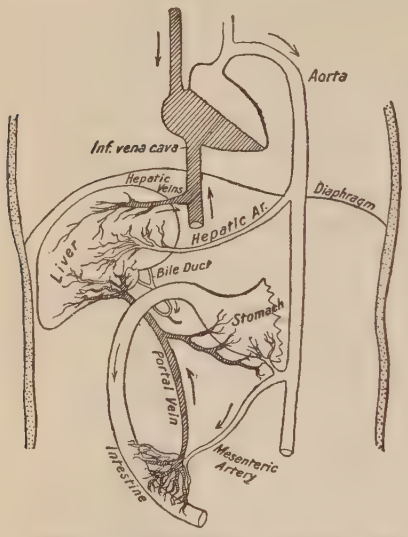

FIG. 69. — **Relations of the liver.** Diagram showing the connection of the liver with the large blood vessels and the food canal.

The liver secretes daily from one to two pounds of a liquid called *bile*. A reservoir for the bile is provided by a small, membranous sack, called the *gall bladder*, located on the underside of the liver. The bile passes from the gall bladder, and from the right and left lobes of the liver, by three separate ducts. These unite to form a common tube which, uniting with the duct from the pancreas, empties into the duodenum. Though usually described as a digestive gland, the liver has other functions of equal or greater importance (Chapter XVIII).

The Bile is a golden yellow liquid, having a slightly alkaline reaction and a very bitter taste. It consists, on the average, of about 97 per cent of water and 3 per cent of solids.[1] The solids include bile pigments, bile salts, a substance called cholesterine, and mineral salts. The pigments (coloring matter) of the bile are derived from the hemoglobin of broken-down red corpuscles (page 29).

Much about the composition of the bile is not understood. It is known, however, to be necessary to digestion, its chief use being to aid in the digestion and absorption of fats. It is claimed also that the bile aids the digestive processes in some general ways — counteracting the acid of the gastric juice, preventing the decomposition of food in the intestines, and stimulating muscular action in the intestinal walls. No enzymes have been discovered in the bile.

The Pancreas is a tapering and somewhat wedge-shaped gland, and is so situated that its larger extremity, or head, is encircled by the duodenum. From here the more slender portion extends across the abdominal cavity nearly parallel to and behind the lower part of the stomach. It has a length of six or eight inches and weighs from two to three and one half ounces. Its secretion, the pancreatic juice, is emptied into the duodenum by a duct which, as a rule, unites with the duct from the liver.

The Pancreatic Juice is a colorless and rather viscid liquid, having an alkaline reaction. It consists of about 97.6 per cent of water and 2.4 per cent of solids. The solids include mineral salts (the chief of which is sodium carbonate) and four different chemical agents, or enzymes, — trypsin, amylopsin, steapsin, and a milk-curding enzyme. These active constituents make of the pancreatic juice the

[1] Hammerstein, *Text-book of Physiological Chemistry.*

most important of the digestive fluids. It acts with vigor on all of the nutrients insoluble in water, producing the following changes:

1. It converts the starch into maltose, completing the work begun by the saliva. This action is due to the *amylopsin*,[1] which is similar to ptyalin but is more vigorous.

2. It changes proteins into peptones and proteoses, completing the work begun by the gastric juice. This is accomplished by the *trypsin*, which is similar to, but more active than, the pepsin.

3. It digests fat. In this work the active agent is the *steapsin*.

The necessity of a milk-curding enzyme, somewhat similar to the rennin of the gastric juice, is not understood.

Digestion of Fat. — Several theories have been proposed at different times regarding the digestion and absorption of fat. Among these, what is known as the "solution theory" seems to have the greatest amount of evidence in its favor. According to this theory, the fat, under the influence of the steapsin, absorbs water and splits into two substances, recognized as glycerine and fatty acid. This finishes the process so far as the glycerine is concerned, as this is soluble in water; but the fatty acid, which (from certain fats) is insoluble in water,[2] requires further treatment. The fatty acid is now supposed to be acted on in one, or both, of the following ways: 1. To be dissolved as fatty acid by the action of the bile (since bile is capable

[1] Amylopsin is absent from the pancreatic juice of infants, a condition which shows that milk and not starch is their natural food.

[2] The fact that butter is more easily digested than other fatty substances is probably due to its consisting largely of a kind of fat which, on splitting, forms a fatty acid (butyric) which is soluble in water.

of dissolving it under certain conditions). 2. To be converted by the sodium carbonate into a form of soap which is soluble in water.

The emulsification of fat is known to occur in the small intestine. By this process the fat is separated into minute particles which are suspended in water, but not changed chemically, the mixture being known as an *emulsion*. While this is believed by some to be an actual process of digestion, the advocates of the solution theory claim that it is a process accompanying and aiding the conversion of fat into fatty acid and glycerine.[1]

The Intestinal Juice is a clear liquid with an alkaline reaction, containing water, mineral salts, and certain protein substances that may act as enzymes. It assists in bringing about an alkaline condition in the small intestine and aids in the reduction of cane sugar and maltose to the simple sugars, dextrose and levulose. Since it is difficult to obtain this liquid in sufficient quantities for experimenting, its uses have not been fully determined. Recent investigators, however, assign to it an important place in the work of digestion.

Work of the Small Intestine. — The small intestine is the most important division of the alimentary canal. It serves as a receptacle for holding the food while it is being acted upon; it secretes the intestinal juice and mixes the food with the digestive fluids; it propels the food toward the large intestine; and, in addition to all this, serves as an organ of absorption.

Digestion is practically finished in the small intestine, and a large portion of the reduced food is here absorbed. There is always present, however, a variable amount of material that is not digested. This, together with a considerable volume of liquid, is passed into

[1] Fischer, *Physiology of Alimentation*.

The Large Intestine. — The large intestine is a tube from five to six feet in length and averaging about one and one half inches in diameter. It begins at the lower right side of the abdominal cavity, forms a coil which almost completely surrounds the coil of small intestine, and finally terminates at the surface of the body (Figs. 2, 68 and 70). It has three divisions, known as the cæcum, the colon, and the rectum.

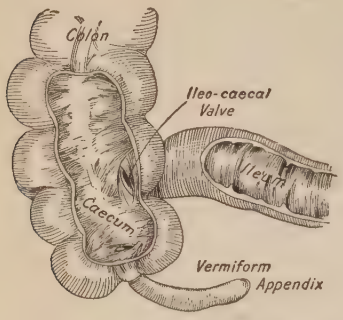

FIG. 70. — **Passage from small into large intestine.** At the ileo-cæcal valve is the narrowest constriction of the food canal.

The cæcum is the pouch-like dilatation of the large intestine which receives the lower end of the small intestine. It measures about two and one half inches in diameter and has extending from one side a short, slender, and blind tube, called the *vermiform appendix*. This structure serves no purpose in digestion, but appears to be the rudiment of an organ which may have served a purpose at some remote period in the history of the human race. The cæcum gradually blends into the second division of the large intestine, called the colon.

The colon consists of four parts, described as the ascending colon, the transverse colon, the descending colon, and the sigmoid flexure, or sigmoid colon. The first three divisions are named from the direction of the movement of materials through them and the last from its shape, which is similar to that of the Greek letter sigma (Σ).

The rectum is the last division of the large intestine.

It is a nearly straight tube, from six to eight inches in length, and connects with the external surface of the body.

The general structure of the large intestine is similar to that of the small intestine, and, like the small intestine, it is held in place by the peritoneum. It differs from the small intestine, however, in its lining of mucous membrane and in the arrangement of the muscular coat. The mucous membrane presents a smooth appearance and has no villi, while the longitudinal layer of the muscular coat is limited to three narrow bands that extend along the greater length of the tube (Fig. 71). These bands are shorter than the coats, and draw the large intestine into a number of shallow pouches, by which it is readily distinguished from the small intestine (Fig. 68).

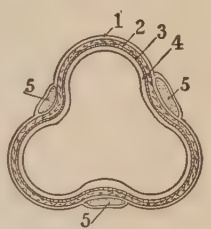

FIG. 71. — **Section of large intestine,** showing the coats. 1. Serous coat. 2. Circular layer of muscle. 3. Submucous coat. 4. Mucous membrane. 5. Muscular bands extending lengthwise over the intestine.

Work of the Large Intestine. — The large intestine serves as a receptacle for the materials from the small intestine. The digestive fluids from the small intestine continue their action here, and the dissolved materials also continue to be absorbed. In these respects the work of the large intestine is similar to that of the small intestine. It does, however, a work peculiar to itself in that it collects and retains undigested food particles, together with other wastes, and ejects them periodically from the canal.

Summary. — The main structure in the digestive system is the alimentary canal. This provides cavities where important dissolving processes take place, and tubes for joining these cavities, while glands connecting with the

canal supply the necessary liquids for changing and dissolving the foods. The general plan of digestion is that of passing the food through the canal, beginning with the mouth, and of acting on it at various places, with the final result of reducing most of it to the liquid state. The digestive fluids supply water which acts as a solvent and carries the active chemical agents, or enzymes, that convert the insoluble foods into substances that are soluble.

Exercises. — 1. State the general purpose of digestion. How does digested food differ from that not digested?

2. Name the divisions of the alimentary canal in the order that food passes through them.

3. What other work besides digestion is carried on by the alimentary canal?

4. What is gained by the mastication of the food? Why should mastication precede the other processes of digestion?

5. What is the work of the tongue in digestion?

6. State the purposes served by the gastric juice.

7. Give reasons for regarding the small intestine as the most important division of the food canal.

8. At what places, and by the action of what liquids, are fats, proteins, and starch digested?

9. What enzymes are found in the pancreatic juice? What is the digestive action of each?

10. Describe the large intestine. What is its main use?

PRACTICAL WORK

Examine a dissectible model of the human abdomen (Fig. 72), noting the form, location, and connection of the different organs. Find the connection of the esophagus with the stomach, of the stomach with the small intestine, and of the small intestine with the large intestine. Sketch a general outline of the cavity, and locate in this outline its chief organs.

Where it is desirable to learn something of the actual structure of the digestive organs, the dissection of the abdomen of some small animal is necessary. On account of unpleasant features likely to be asso-

ciated with such a dissection, however, this work is not recommended for immature pupils.

To Show the Importance of Mastication. — Fill two tumblers each half full of water. Into one put a lump of rock salt. Into the other place an equal amount of salt that has been finely pulverized. Which dissolves first and why?

To Illustrate Acid and Alkaline Reactions. — To a tumbler half full of water add a teaspoonful of hydrochloric or other acid, as vinegar. To a second tumbler half full of water add an equal amount of cooking soda. Taste each liquid, noting the sour taste of the acid and the alkaline taste of the soda. Hold a piece of red litmus paper in the soda solution, noting that it is turned blue. Then hold a piece of blue litmus paper in the acid solution, noting that it is turned red. Add acid to the soda solution, and soda to the acid solution, until the conditions are reversed, testing with the red and blue litmus papers.

FIG. 72. — **Model** for demonstrating the abdomen and its contents.

Hold, for a minute or longer, a narrow strip of red litmus paper in the mouth, noting any change in the color of the paper. Repeat, using blue litmus paper. What effect, if any, has the saliva upon the color of the papers? Has the mouth an acid or an alkaline reaction?

To Show the Action of Saliva on Starch. — 1 (Optional). Prepare starch paste by mixing half a teaspoonful of starch in half a pint of water and heating the mixture to boiling. Place some of this in a test tube and thin it by adding more water. Then add a small drop of weak iodin solution [1] to the solution of starch. It should turn a deep blue color. This is the test for starch.

Now collect from the mouth, in a clean test tube, two or three teaspoonfuls of saliva. Add portions of this to small amounts of fresh starch solution in two test tubes. Let the tubes stand for five or ten minutes surrounded by water having about the temperature of the body. Test for changes that have occurred as follows:

(*a*) To one tube add a little of the iodin solution. If it does not

[1] To prepare iodin solution, dissolve a crystal of iodin in one-fifth pint of a weak solution of potassium iodid in water and add water to this until it is a light amber color.

turn blue, it shows that the starch has been converted into some other substance by the saliva. (*b*) To the other tube add a few drops of a very dilute solution of copper sulphate. Then add sodium (or potassium) hydroxide, a few drops at a time, until the precipitate which first forms dissolves and turns a deep blue. Then gradually heat the upper portion of the liquid to boiling. If it turns an orange or yellowish red color, the presence of a form of sugar (maltose or dextrose) is proved.

2. Hold some powdered starch in the mouth until it completely dissolves and observe that it gradually acquires a sweetish taste. This shows the change of starch into sugar.

To Illustrate the Action of the Gastric Juice. — Add to a tumbler two-thirds full of water as much scale pepsin (obtained from a drug store) as will stay on the end of the large blade of a penknife. Then add enough hydrochloric acid to give a slightly sour taste. Place in the artificial gastric juice thus prepared some boiled white of egg which has been finely divided by pressing it through a piece of wire gauze. Also drop in a single large lump. Keep in a warm place (about the temperature of the body) for several hours or a day, examining from time to time. What is the general effect of the artificial gastric juice upon the egg? How does the effect upon the finely divided egg differ from the effect upon the single large lump? Inferences.

To Illustrate Effect of Alcohol upon Gastric Digestion. — Prepare a tumbler half full of artificial gastric juice as in the above experiment, and add 10 cc. of this to each of six clean test tubes bearing labels. To five of the tubes add alcohol from a burette as follows: (1) .5 cc., (2) 1 cc., (3) 1.5 cc., (4) 2 cc., and (5) 3 cc., leaving one tube without alcohol. Now add to each tube about $\frac{1}{4}$ gram of finely divided white of egg from the experiment above, and place all of the tubes in a beaker half full of water. Keep the water a little above the temperature of the body for several hours, examining the tubes at intervals to note the progress of digestion. Inferences.

CHAPTER XIV

HYGIENE OF THE MOUTH

Just as mastication is the beginning process of digestion, proper care of the mouth is the first step in the maintenance of health throughout the digestive system. The healthy mouth is also a necessary condition to the health of the entire body.

Problems in Mouth Hygiene. — These may be grouped under three main heads — the preservation of the teeth, prevention of infections of the gums and at the roots of teeth, and avoidance of irregularities of the teeth and jaws. In the solution of these problems, we have five lines of practical effort, as follows:

1. That of keeping the entire mouth clean.
2. That of having all decayed places properly filled as soon as they occur.
3. That of avoiding conditions that lead to infections of the gums.
4. That of avoiding conditions that lead to tooth abscess.
5. That of securing competent aid for the relief of malocclusion and tooth impact.

To Keep the Mouth Clean. — The necessity for mouth cleanliness lies in two main facts. First, food remaining in the mouth decays and forms acids which attack and destroy the enamel, thereby starting decay in the teeth. Second, the decaying food supplies a very rich field for the propagation of germs which may do harm in the mouth itself and spread to other parts of the body. Mouth cleansing includes,

1. *Brushing the teeth.* This should be done by an upward and downward stroke of the brush and as often, in some cases, as four times a day — on rising and after each meal.[1] Ordinarily only pure water is necessary, but occasionally a scouring substance (tooth powder or paste) may be used to remove stains or closely adhering food particles.

2. *Removal of substances from between the teeth.* This is done either by means of a toothpick or with dental floss. The latter is more frequently recommended because of the danger of irritating the gums with the pick. However, if one is careful he can easily remove the food particles without injuring the gums. The simple rule is to pick the teeth and avoid picking at the gums.

3. *Mouth rinsing.* The mouth is rinsed by filling it two-thirds full of water and forcing this between the teeth and against the cheeks by strong contractions of the cheek muscles, after which the water is expelled from the mouth. This is necessary for getting the entire mouth clean.

4. *Special cleaning of the teeth by the dentist.* The purpose of dental cleaning is to remove from the teeth substances which cannot be removed by the individual. These include a limy deposit called tartar, which collects on the teeth just under the gums, and stains and deposits on the exposed parts of the teeth. Most teeth should be cleaned by the dentist at least once a year.

Necessity for Promptness in Securing Dental Aid. — Our only means of stopping tooth decay after it has once started is by having the decayed places filled by the dentist. Since the longer the decayed place is neglected, the larger it becomes, and since decay in one tooth may start decay

[1] If the teeth are brushed but once a day, this should be on retiring at night. It is during the night that anything left in the mouth has the best chance to decay and form harmful acids.

in the teeth next to it, there is economy both of money and of nervous energy in getting dental aid at the earliest moment. Promptness in this matter should also be a part of our program for preserving our natural teeth and for the following reason:

The larger cavities can never be so successfully filled as the smaller ones and, as a consequence, the fillings have to be replaced much more frequently. To replace a filling nearly always means the enlargement of the cavity, and when this reaches the pulp, the nerve must be killed.[1]

Nature and Cause of Infections of the Gums. — Healthy gums are of a light pink color, fit snugly to the teeth, and have tiny upward projections between the teeth. Infected gums are red, or inflamed, and are usually swollen. They also draw away from the teeth, leaving space for the collection of food and germs. Infections of the gums are fully as serious as tooth decay and, like tooth decay, cause, in many instances, the loss of teeth.[2]

Although the result of germs, gum infections do not have germs as their primary cause. This is found in conditions that lower the local resistance (p. 108) of the gums to the point where germs can make a successful attack.

[1] Dead teeth are a source of much trouble from abscesses at their roots, and very frequently have to be extracted. If we are to keep our natural teeth until we are old, we must see that needed dental work is promptly attended to when we are young. Indeed it is a good plan not to wait until we have discovered a decayed place ourselves, but to have the teeth carefully examined twice a year by the dentist in order to find beginning places of decay.

[2] One of the most serious of the gum infections is the disease known as *pyorrhea*. This is a chronic infection which begins at the junction of the gum with the tooth and works down in the membrane surrounding the root (the peridental). It may also destroy the part of the jawbone lining the socket. If it is not checked, it causes the teeth to loosen and come out. Pyorrhea is a very common disease and often exists unnoticed in the mouth as it causes little or no pain. Germs from pyorrhea sores are swallowed with the food and absorbed by the blood, to be carried all over the body.

Conditions that, by Lowering the Resistance of the Gums, Pave the Way for Germ Attacks. — According to different authorities, these are of three kinds, as follows:

1. *Mechanical irritations.* These include irritation from the tartar, from poorly fitted crowns whose sharp edges cut into the gums, and from the toothpick which is improperly used.

2. *Chemical irritation.* Acid formed by the decay of food in the mouth supplies the chief cause for this. In the unkept mouth the food is very apt to collect in the small groove between the gum and the tooth and decay there.

3. *Thermal irritation.* This means irritation from extremes of temperature. Overhot substances are considered especially harmful both to the tooth enamel and to the peridental membrane.

Methods of Prevention and of Relief. — The method of prevention is simply that of avoiding the causes, as explained above, that lead to a weakening of the gum structures. If the gums are weak but not as yet diseased, as indicated by their bleeding easily, one should in addition to removing the cause or causes that exist, massage them vigorously twice a week with a finger dipped in strong salt water. This improves the circulation and greatly improves their resistance. If the gums are actually diseased, one should promptly consult a dentist. Gum infections seldom get well of themselves, even when the beginning cause is removed.

To Avoid and Relieve Tooth Abscesses.[1] — These occur, for the most part, at the roots of teeth in which the

[1] The tooth abscess is aptly described as a boil at the root of a tooth. It is an infection (caused by germs) and is usually painful. There are tooth abscesses, however, which are not painful, as the pus is taken up by the blood as fast as it is formed. Tooth abscesses, whether painful or not, endanger the whole body by the spreading of germs through the blood.

nerve has been destroyed. These so-called "dead teeth" have at their roots places of low local resistance, and germs may get to these places either by traveling down the tooth canal (Fig. 73) or by coming through the blood. To avoid tooth abscess in the first place, we must prevent tooth decay — keeping the mouth perfectly clean and getting decayed places filled as soon as possible. To obtain relief when the trouble has started, we must see the dentist. To entirely cure the condition, it is necessary in most cases to extract the tooth.[1]

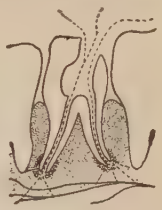

FIG. 73. — **Showing the passage of germs** down a badly decayed and unfilled tooth and the spread of germs from the abscess at the root to adjacent teeth and to the blood. The dotted lines show the path followed by germs.

Relief from Malocclusion[2] **and Irregularities.** — One function of the teeth is to add to the personal appearance. It is always a pity to have the expression spoiled by a mouthful of irregular teeth or by a bad closing of the jaws. Fortunately these defects can be remedied, and we now have specializing dentists who give their entire time to the correction of such defects.

Impacted Teeth. — These are teeth that have not been cut, but have remained imbedded in the jaws on account of obstruction. Their presence is shown by X-ray pictures of the jaws (Fig. 74). In some cases they are a great

[1] The effort to cure tooth abscess by treatment is usually unsuccessful because of the smallness of the tooth canals. On account of their size it is often impossible to get the germ-destroying medicines into the infected area in sufficient amount.

[2] Malocclusion means a bad closing of the jaws. It is a condition in which the rows of teeth do not meet as they should. In normal closing of the jaws, the side teeth meet squarely, while the lower front teeth glide in back of the upper front teeth (p. 142). We have malocclusion when the side teeth do not meet squarely, when the lower jaw in front projects beyond the upper, and when the lower jaw recedes, leaving a space between the upper and lower front teeth when the mouth is closed.

irritation to the nerves on account of the pressure which they exert. Headache, neuralgia, nervousness, St. Vitus's dance, and spasms may result from this cause. Impacted teeth are extracted by first making an incision in the jawbone.

When Teeth Should be Extracted. — Although one purpose of mouth hygiene is to preserve the teeth, a larger aim is to keep up and improve the health of the entire body. Hence, it is often necessary to sacrifice a tooth in order that the greater purpose be served. In cases of tooth abscess and of pyorrhea which cannot be cured, and also in most cases of impacted teeth, we gain immensely by extraction. The germs from the chronic abscess or from pyorrhea sores would do vastly more harm than the crippled teeth could do good, and the same is true of the nervous disturbances resulting from impacted teeth.

FIG. 74. — **An impacted wisdom tooth.** Drawn from X-ray picture supplied through courtesy of Charles Carroll Linton, D.D.S., New York City.

Effects of Foods and Habits of Eating upon the Teeth. — Foods that require chewing are considered much better for the teeth than soft and mushy foods that require little or no chewing. Candy is perhaps the worst food enemy of the teeth, especially when it is eaten between meals. To avoid harm to the teeth, as well as to the stomach, it should be eaten during or just following meals. Good teeth also require a well balanced diet (p. 132), and those having teeth that decay easily should include several foods that are rich in mineral salts and vitamines. They should have a pint or more of pure, whole milk per day and

a fair allowance of orange juice or the juice from raw tomatoes.

Care of the Temporary Teeth. — According to expert opinion, the temporary teeth are as deserving of proper care as the permanent teeth, this being necessary both for the immediate purpose which they serve and for the good effect which, if kept sound, they have upon the permanent teeth. The temporary teeth should be kept clean and all decaying places should be promptly filled. Although a temporary tooth which does not come out naturally at the time that the permanent tooth is coming in should be extracted, it is a great mistake to pull it before this time. It must be left in to hold the space for the permanent tooth.

The Six-year Molars. — These are the first of the permanent teeth to appear and are so named because they are cut when the child is about six years old. Since they come immediately back of the temporary teeth, they are often mistaken for teeth belonging to this set and neglected for the same reason that the temporary teeth are. They require special attention from the fact that they are permanent teeth and because they frequently begin to decay at an early age. Decay in any of these four teeth should be looked after immediately.

Summary. — To keep our natural teeth as long as we live, we must form the habit of looking after the mouth carefully when we are young. We must keep the teeth clean, get needed dental work done at the earliest moment, avoid all kinds of irritations of the gums, and take every precaution to prevent infections in any part of the mouth. Good digestion, health in general, and a good appearance are all dependent upon a healthy mouth.

Exercises. — 1. State the main problems of mouth hygiene. Along what lines do we work in solving these problems?

2. In what ways may a bad condition of the mouth injure the whole body?

3. How may a bad condition of the mouth interfere with one's work at school?

4. Name the parts of a tooth. What different kinds of materials form it? What purpose is served by the enamel?

5. How does tooth decay get started? How is it checked? How is it prevented in the first place?

6. Describe the series of bad effects that follow neglect of decaying teeth.

7. Describe the proper method of using the tooth brush. Of using the tooth pick.

8. State the nature and cause of pyorrhea. How is it cured? How avoided?

9. State the nature and cause of tooth abscess. How is it relieved? How is it prevented?

10. Describe the condition called malocclusion. That of impacted teeth. How is relief from both conditions secured?

11. Why should the temporary teeth receive the same careful treatment as the permanent?

12. What teeth are called the six-year molars? Why should they have special attention?

CHAPTER XV

HYGIENE OF THE ORGANS AND PROCESSES OF DIGESTION

Every one knows the importance of good digestion, though few realize to what extent this depends upon the person himself. A careful study of the problem shows that the digestion of food and the condition of the digestive organs are greatly influenced by our methods of living.

Importance of the Digestive Fluids. — Recalling the fact that digestion is a complicated process of dissolving, we can see how important the liquids are that do the dissolving. If these are secreted in sufficient amounts and are of the right quality, and if they are brought in contact with the food in the right manner, good digestion will result. On the other hand, if they are insufficient in amount or of a poor quality, or if there be interference with their action, digestion cannot take place as it should.

Simple Rules of Eating. — To obtain the best results from the digestive fluids we must put into daily practice the following rules:

1. Being hungry at mealtime.
2. Eating slowly and masticating thoroughly.
3. Enjoyment of meals and cheerfulness while eating.
4. Using foods that require chewing in preference to liquids and soft foods that can be swallowed without chewing.
5. Avoidance of overeating and eating between meals.

The value of these rules lies in the fact that the digestive fluids are secreted largely at the time of eating and not

afterwards. This makes of mealtime a period of special importance.

Hunger at Mealtime. — Hunger is the strongest of all the stimuli for exciting the digestive glands. Hungry boys and girls who have had to wait for their dinners know how the odor and even the thought of food cause the saliva to flow. But the problem is to be hungry at mealtime — the time when we need the digestive juices. This problem is solved largely by getting plenty of exercise previous to the meal. Exercise, by using up food already at the cells, creates a demand for more food, and it is this that gives the appetite. But in addition to exercising, we must avoid overeating at the previous meal and eating between meals. Either one will spoil the appetite for the next meal.

Importance of Chewing. — Chewing serves as a mechanical stimulus to the digestive glands and also breaks up the solid masses of food, thereby giving more surface for the digestive fluids to act upon. Thorough chewing is also better for the teeth, giving them needed exercise, and it is a real aid in keeping them clean and sound. We should early form the habit of thorough mastication, and this requires special thought and effort at each meal.

Effect of our Mental States. — The mental states have a decided effect upon the secretion of the digestive juices. Anger, worry, and conditions of mental strain have the effect of closing the glands, as it were, and of causing them to hold back their juices. Cheerful and agreeable mental states and freedom from strain have the opposite effect. While we should, of course, be agreeable and cheerful at all times, we should make a special effort to be so while eating.

Overeating and the Work of Digestion. — Although overeating is harmful in many ways, it is especially bad for the digestion. Since a given amount of digestive fluid

is required for a given amount of food, and since the amount of fluid that can be secreted at any time is limited, it is easy to eat more than can be properly digested. And then, as already explained, overeating at one meal dulls the appetite for the next meal, and this, in turn, lessens the juices that will be secreted.

Poisoning from Waste Accumulations in the Food Canal. — The food canal, especially the large intestine, is often referred to as the " body sewer." Not only must it expel the undigested food, but also wastes that are emptied into it from the liver and other glands. Although a temporary collection of waste in the canal does, perhaps, no harm, a constant accumulation is a serious condition. For one thing, the waste is apt to decay in the intestines and form poisons which are absorbed into the blood and carried all over the body. These injure the nerves and do harm in other ways.[1] The waste that is not so absorbed interferes with digestion and injures the delicate linings of the food canal.

Causes of Waste Accumulations. — If one is to avoid an excess of waste in the food canal, he must understand the causes leading to this condition and the means for removing them. The more important of the causes are the following:

1. *Eating while the stomach still contains undigested food.* This left-over material may result from overeating at the preceding meal or from eating between meals. By mixing with food that is entering, it is likely to be held in the stomach until it decays.

[1] Poisons from decomposing wastes in the food canal are the chief cause of the *auto-intoxication*, or self-poisoning, which physicians so frequently find among their patients. Headache, dullness, chronic fatigue, and other symptoms which appear when one is said to be *bilious* usually result from decaying waste.

2. *Eating foods that one cannot digest.* Many people are unable to digest certain foods. When one knows what these are he should avoid them.

3. *Constipation.* By this is meant an unnaturally slow movement of materials through the canal. In pronounced cases the bowels may not move for a day or more, and this has the effect of stopping, for the time, the "body sewer." Constipation stands first among the causes of waste accumulation in the food canal.

Indications of Constipation. — Conditions that suggest that wastes are not being passed rapidly enough from the food canal are a bad condition at the mouth — coated tongue, foul breath, etc.; sallowness of the complexion; a feeling of fullness in the abdomen; and headache, dullness, and chronic fatigue. When some or all of these symptoms are present, we should investigate our methods of living to see what may be done to make the bowels more active.

Causes of Constipation. — Although materials are pushed along the food canal by contraction of the muscles within its walls (pp. 150, 152, and 159), the success of the contractions depends upon many things. There are, therefore, quite a number of causes for materials moving too slowly through the canal, such as:

1. Lack of good tone (p. 257) in the intestinal muscles.
2. Abrupt bends in intestines due to misplacements.
3. A run-down condition of the nervous system.
4. The drinking of too little water.
5. The eating of an insufficient amount of coarse food.

These causes can all be avoided.

To Improve the Intestinal Muscles. — Since these muscles are not under the control of the mind, and cannot be exercised directly, we must improve them by indirect

means. One valuable way of doing this is through exercise of the muscles in the walls of the abdomen. As these muscles contract and relax, they massage the intestines, and this, by improving the circulation in them, increases the tone and strength of their muscles. All kinds of trunk bending and twisting are valuable for this purpose, though the head-lifting exercise taken on retiring at night (p. 272) is one of the most satisfactory.

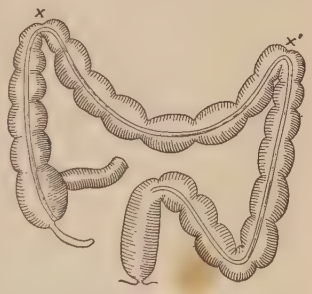

FIG. 75. — **Showing central misplaced section of large intestine** causing abrupt bends, or kinks, at x and x'.

To Prevent Obstruction of the Canal from Misplacements. — There are two main causes for the stomach and intestines getting out of their natural positions. These are weak abdominal walls and incorrect posture. On account of the weak walls, the intestines are deprived of their natural support, and from a drooped-over position in standing or sitting, the abdominal contents are all more or less depressed. From the combined effect of these two causes, the stomach and certain coils of intestines may be displaced downward several inches. When this occurs, the stomach may have trouble in emptying into the small intestine and abrupt bends are formed in the large intestine (Fig. 75) that obstruct the waste. The remedy, of course, is to keep the walls of the abdomen strong through exercise [1] and to maintain correct posture, as explained in Chapter XX.

[1] In addition to their supporting and massaging effect upon the intestines, strong abdominal walls are also our best protection against *hernia*, or rupture. This is a condition in which the abdominal walls are actually broken, except for their inner and outer layers of membrane and skin. It is a serious condition and one that is altogether too common.

Constipation and the Nervous System. — Since the intestinal muscles are under the control of nerves, they cannot work vigorously unless the nerves themselves are in good condition. A great aid, therefore, in keeping the bowels active is to conserve the nervous energy, as explained in Chapter XXVI. Since a special nervous reaction is necessary for relieving the bowels, we should observe a regular time each day for going to the toilet. This is in keeping with the established fact that all the bodily activities tend to occur in periodic sequence.

The Drinking of Sufficient Water. — Water keeps the waste in the food canal soft and adds to its bulk. For these and other reasons it is a most important aid in the avoidance of constipation. A couple of glasses of water before breakfast are especially valuable for this purpose. We should also drink one or two glasses at each meal and an equal amount between meals.

Value of Coarse Food. — Food that contains considerable material that is not digested is much better for keeping the bowels active than food that is almost entirely digested. This is because the residue, or bulk, that remains in the canal after digestion, acts as a stimulus to the intestinal muscles. On this account, each meal should contain some coarse food, such as corn bread, cabbage, lettuce, celery, and apples or other fruit.

Constipation and Right Living. — There is every reason to believe that constipation is the result of wrong living and that it is to be cured and prevented by right living. By living in such manner as to keep the muscles in the walls of the intestines and abdomen in good tone; by keeping our bodies in their natural shape; by conserving our nervous energy; and by living rightly with reference to our food and the drinking of water, we can easily conquer this

great enemy of good health. Should we be living rightly as far as we know and still be constipated, we should consult a physician.

To Avoid Germ Attacks in the Food Canal. — The food canal, like the air passages, is subject to attacks of germs. Typhoid fever, cholera, appendicitis, and catarrh of the stomach and intestines are all caused in this way. We can defend ourselves from such attacks by three methods, as follows:

1. *By the destruction of germs that may be present in our food or in the water we drink.* This is done by thoroughly cooking our food and boiling our drinking water when we are not sure that they are free from dangerous germs.[1] This is one of the most important ways of preventing typhoid fever.

2. *By keeping germs from mixing with the food while it is being masticated and swallowed.* This is done by keeping the mouth healthy, as explained in the preceding chapter, and by keeping the nose and throat free from infections, as explained in Chapter XI. This is of the greatest importance.

3. *By protecting the linings of the food canal from all kinds of injuries.* Disease germs may pass through the canal without doing harm if only the mucous linings are kept healthy and in high resistance. In the matter of keeping them healthy, we must again apply the principles of right living.

[1] Not only is water that has the odor or taste of decay and that is not perfectly clear, likely to contain germs, but clear water without odor may also contain them. Hence, one must be guided by conditions in determining what should be done. The city water during an epidemic of typhoid fever, and also the water used by the family in which a member is sick with typhoid, should be boiled. Water from a well, cistern, or other place of supply that receives surface drainage should also be boiled before using.

To Keep Linings of Food Canal Healthy. — To protect the linings of the stomach and intestines, we must attend to a number of things, as follows:

1. *We must keep the mouth and throat healthy.* This will protect the stomach lining from germs from these places.

2. *We must avoid irritating substances in our food*, such as pepper, mustard, sour pickles, and fruits that are strongly acid. The users of strong drink have suffered greatly from the irritating effect of alcohol on the stomach.[1]

3. *We must avoid hot foods and drinks.* These cause an excess flow of blood into the stomach lining that may be very damaging. Foods and drinks only comfortably warm, however, are probably not harmful in this respect.

4. *We must avoid eating between meals*, especially the eating of candy. Candy should be eaten during or just following the meal. Taken on an empty stomach it is irritating.

5. *We must practice thorough mastication.* This reduces the rough bits of food and covers all portions with non-irritating saliva.

6. *We must drink plenty of water.* Water is non-irritating in itself, and it dilutes and carries along everything that is irritating.

7. *We must avoid indigestion and constipation.* Indigestion causes injury to the linings through the acids and other irritating substances that are formed, while constipation causes injury through mechanical irritation.

[1] Dr. William Beaumont, an American surgeon of the last century, made a series of observations upon a human stomach (that of Alexis St. Martin) having an artificial opening, the result of a gunshot wound. Much of our knowledge of the digestion of different foods was obtained through these observations. In spite of the protests of his physician, St. Martin would occasionally indulge in strong drink and always with the same result — the lining of the stomach became much inflamed and very sensitive, and the natural processes of digestion were for the time suspended.

We also protect the linings of the food canal by avoiding prolonged chilling, as in the case of the linings of the air passages (p. 111).

To Prevent Appendicitis. — This well-known disease is the result of a germ attack within the appendix vermiformis (p. 158). It is a serious ailment and often requires an expensive and dangerous operation for its cure. How much better, then, to prevent it in the first place, as can be done in many instances by the kind of right living described in this chapter. The disease does not, as a rule, occur when the linings of the food canal are healthy, but is the result of a state of low local resistance.[1] To prevent appendicitis we must avoid the conditions, named above, that injure the linings of the canal. The other causes of appendicitis, besides that of low local resistance, are almost negligible.

Tea and Coffee. — The starting point in both mild and serious troubles of the digestive organs is often found in the use of tea and coffee. Harm results from the universal custom of drinking these beverages hot, as well as from the irritating substances which they contain when boiled or steeped in their preparation. Besides injuring the digestion, coffee and tea, through the drug caffeine, may weaken the nerves and interfere with the heart. This drug also forms a waste (uric acid) which is removed with difficulty by the kidneys and which may be a cause of injury to them. While there is a difference of opinion as to the use of tea and coffee by adults, all are agreed that growing children and those nervously weak should leave them alone.

[1] While germ attacks can and do occur in other parts of the canal, they are never so serious as when they occur in the appendix. For one thing, the small opening at the upper end of the appendix prevents a natural discharge from the sore and this keeps the infection from getting well of itself.

Summary. — Good digestion and a healthy condition of the digestive organs is the third of our foundations of health and, like our other foundations, is to be kept up by right living. We must live right with reference to our food, our methods of eating, and in our care of the mouth. We must live right in respect to conditions that affect the activity of the bowels. And we must live right in the matter of doing things that affect the health and resistance of the linings of the food canal. No kinds of right living are more important than these.

Exercises. — 1. State the purpose of the digestive fluids. Why does a heavy meal require more of them than a light meal?

2. What methods of eating will secure the greatest flow of these fluids?

3. How does being hungry at mealtime aid in good digestion? How can we be hungry at that time?

4. How does overeating cause indigestion? How does eating between meals do the same thing?

5. What harm results from waste accumulating in the food canal? What causes are responsible for this condition?

6. State the main causes of constipation. Why may we regard it as a result of wrong living?

7. How may weak abdominal muscles cause constipation? How incorrect posture?

8. State value of plenty of water in correcting constipation. Of coarse foods. Of good nerves.

9. What serious troubles result from germ attacks in the food canal? What is the general plan of prevention?

10. Discuss methods by which the linings of the food canal are kept in a state of high resistance.

11. State the nature of appendicitis. How may we work to prevent it?

12. In what respects is prevention of this disease better than its cure?

13. Give reasons for calling good digestion a health foundation.

14. How do sufficient exercise, mouth cleanliness, correct posture, regular habits of eating, and a happy disposition aid in keeping it up?

CHAPTER XVI

ABSORPTION, STORAGE, AND ASSIMILATION

The dissolved nutrients, to reach the cells, must be transferred from the alimentary canal to the blood stream. This process is known as *absorption*. In general, absorption means the penetration of a liquid into the pores of a solid, and takes place according to the simple laws of molecular movements. The absorption of food is, however, not a simple process, and the passage takes place through an *active* (living) membrane. Another difference is that certain foods undergo chemical change while being absorbed.

Small Intestine as an Organ of Absorption. — While absorption may occur to a greater or less extent along the entire length of the alimentary canal, most of it takes place at the small intestine. Its great length, its small diameter, and its numerous blood vessels all adapt the small intestine to the work of absorption. The transverse folds in the mucous membrane, by retarding the food in its passage and by increasing the absorbing surface, also aid in the process. But of greatest importance are the minute elevations that cover the surface of the mucous membrane, known as

The Villi. — Each single elevation, or villus, has a length of about one fiftieth of an inch and a diameter about half as great (*A*, Fig. 76), and contains the following essential parts:

1. An outer layer of epithelial cells, resting upon a connective tissue support.

2. A small lymph tube, called a *lacteal*, which occupies the center of the villus and connects at the base with other lymph tubes, also called lacteals (*B*, Fig. 76).

3. A network of capillaries.

The villi are structures especially adapted to the work of absorption, and they are found only in the small intestine.

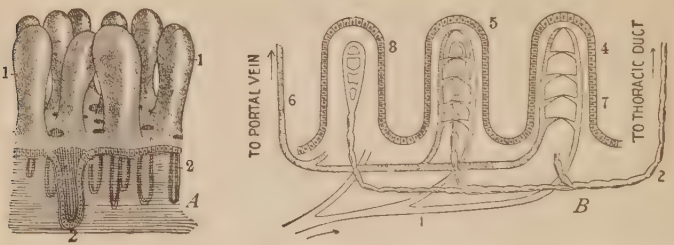

FIG. 76. — **The villi.** *A*. Diagram of a small section of mucous membrane of small intestine. 1. Villi. 2. Small glands, called *crypts*.

B. Diagram showing structure of villi. 1. Small artery. 2. Lacteal. 3. Villus showing termination of the lacteal. 4. Villus showing capillaries. 5. Villus showing both the lacteal and the capillaries. 6. Small vein. 7. Layer of epithelial cells.

The mucous membrane in all parts of the canal, however, is capable of taking up some of the digested materials.

Work of Capillaries and Lacteals. — The capillaries and lacteals act as receivers of material as it passes through the layer of epithelial cells covering the mucous membrane. The lacteals take up the digested fats,[1] and the capillaries receive all the other kinds of nutrients. These vessels do not, of course, retain the absorbed materials, but pass them on. Their final destination is the general circulation, which they reach by two well-defined channels, or routes.

Routes to the Circulation. — The two routes from the

[1] The lacteals (from the Latin *lacteus*, milky) are so called on account of their appearance, which is white, or milk-like, due to the fat droplets.

place of absorption to the general circulation are as follows:

1. *Route taken by the Fat.* — The fat is conveyed by the lacteals from the villi to the receptacle of the chyle. At this place it mingles with the lymph from the lower parts of the body, and with it passes through the thoracic duct to the left subclavian vein. Here it enters the general circulation. Thus, to reach the general circulation, the fat has to pass through the villi, the lacteals, the receptacle of the chyle, and the thoracic duct (Fig. 77). Its passage through these places, like the movements in all lymph vessels, is slow, and it is only gradually admitted to the blood stream.

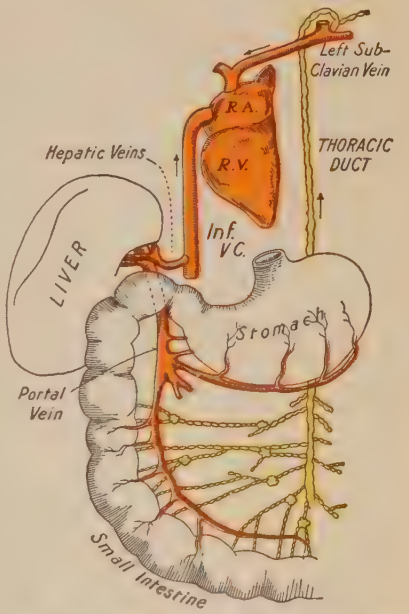

FIG. 77. — **Diagram of routes** from food canal to general circulation. See text.

2. *Route of All the Nutrients except Fat.* — Water and salts and the digested proteins and carbohydrates, in passing into the capillaries, mix there with the blood. But this blood, instead of flowing directly to the heart, is passed through the portal vein to the liver, where it enters a *second set of capillaries* and is brought very near the liver cells. From the liver it is passed through the hepatic veins into the inferior vena cava, and

by these it is emptied into the right auricle. This route then includes the capillaries in the mucous membrane of the stomach and intestines, the branches of the portal vein, the portal vein proper, the liver, and the hepatic veins (Fig. 77). In passing through the liver, a large portion of the food material is temporarily retained for a purpose and in a manner to be described later (page 185).

Absorption Changes. — During digestion the insoluble foods are converted into certain soluble materials, such as peptones, maltose, and glycerine, — the conversion being necessary to their solution. A natural supposition is that these materials enter and become a part of the blood, but examination shows them to be absent from this liquid. (See Composition of the Blood, page 32.) There are present in the blood, however, substances closely related to the peptones, maltose, glycerine, etc.; substances which have in fact been formed from them. During their transfer from the food canal, the dissolved nutrients undergo changes, giving rise to the materials in the blood. Thus are the serum albumin and serum globulin of the blood derived from the peptones and proteoses; the dextrose, from the maltose and other forms of sugar; and the fat droplets, from the glycerine, fatty acid, and soluble soap.

While considerable doubt exists as to the cause of these changes and as to the places also where some of them occur, their purpose is quite apparent. The materials forming the dissolved foods, although adapted to absorption, are not suited to the needs of the body, and if introduced in this form are likely to interfere with its work.[1] They are changed, therefore, into the forms which the body can use.

[1] Peptones and proteoses, when injected directly into the blood, are found to act as poisons.

A Second Purpose of Digestion. — Comparing the digestive changes with those of absorption, it is found that they are of a directly opposite nature; that while digestion is a process of tearing down, or separating, — one which reduces the food to a more finely divided condition — there is in absorption a process of building up. From the comparatively simple compounds formed by digestion, there are formed during absorption the more complex compounds of the blood. The one exception is dextrose, which is a simple sugar; but even this is combined in the liver and the muscles to form the more complex compound known as glycogen. (See Methods of Storage, below.) These facts have suggested a second purpose of digestion — that of reducing foods to forms sufficiently simple to enable the body to construct out of them the more complex materials that it needs. Evidence that digestion serves such a purpose is found in the fact that both proteins and carbohydrates are reduced to a simpler form than is necessary for dissolving them.[1]

The Storage of Nutriment. — For some time after the taking of a meal, food materials are being absorbed more rapidly than they can be used by the cells. Following this is an interval when the body is taking no food, but during which the cells must be supplied with nourishment. It also happens that the total amount of food absorbed during a long interval may be in excess of the needs of the cells during that time; and it is always possible, as in disease, that the quantity absorbed is not equal to that consumed. To provide against emergencies, and to keep up a uniform supply of food to the cells, it is necessary that the body store up nutrients in excess of its needs.

Methods of Storage. — The general plan of storage varies with the different nutrients as follows:

1. *The carbohydrates* are stored in the form of *glycogen.* This, as already stated (page 124), is a substance closely resembling starch. It is stored in the cells of both the

[1] The soluble double sugars (maltose, milk sugar, and cane sugar) are reduced to the simple sugars (dextrose and levulose). Furthermore the action on the proteins does not stop with the production of peptones and proteoses, but these in turn are still further reduced.

liver and the muscles, but mainly in the liver (Fig. 78). It is a chief function of the liver to collect the excess of dextrose from the blood passing through it, and to convert it into glycogen, which it then stores within its cells. It does not, however, separate all of the dextrose from the blood, a small amount being left for supplying the immediate needs of the tissues. As this is used, the glycogen in the liver is changed back to dextrose and, dissolving, again finds its way into the blood. In this way, the amount of dextrose in the blood is kept practically constant. The carbohydrates are stored also by converting them into fat.

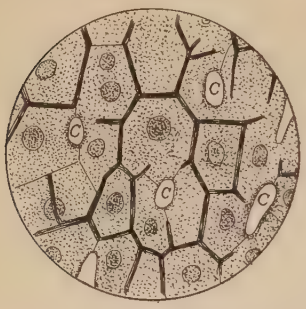

FIG. 78. — **Liver cells** where is stored the glycogen. *C*. Capillaries.

2. *The fat* is stored for the most part in the connective tissue. Certain of the connective tissue cells have the property of taking fat from the blood and of depositing it within their inclosing membranes (Fig. 79). When this is done to excess, and the cells become filled with fat, they form the so-called *adipose tissue*. Most of this tissue is found under the skin, between the muscles, and among the organs occupying the abdominal cavity. If one readily takes on fat, it may also collect in the

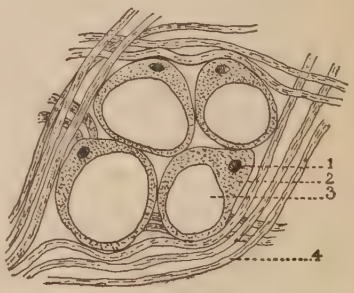

FIG. 79. — **Stored-up fat.** The figure shows four connective tissue cells containing small particles of fat. 1. Nucleus. 2. Protoplasm. 3. Fat. 4. Connective tissue fibers.

connective tissue around the heart. The stored-up fat is redissolved as needed, and enters the blood, where it again becomes available to the active cells.

3. *The proteins* form a part of all the tissues, and for this reason are stored in larger quantities than any of the other food substances. The large amount of protein found in the blood may also be looked upon as storage material. The proteins in the various tissues are spoken of as *tissue proteins*, and those in the blood as *circulating proteins*. The proteins of the tissues serve the double purpose of forming a working part of the cell protoplasm, and of supplying reserve food material. That they are available for supplying energy, and are properly regarded as *storage material*, is shown by the rapid loss of protein in starving animals. When the proteins are eaten in excess of the body's need for rebuilding the tissues, they are supposed to be broken up in such a manner as to form glycogen and fat, which may then be stored in ways already described.

General Facts Relating to Storage. — The form into which the food is converted for storage in the body is that of *solids* — the form that takes up the least amount of space. These solids are of such a nature that they can be changed back into their former condition and, by dissolving, reënter the blood.

Only energy-yielding foods are stored. Water and salts, though they may be absorbed in excess of the needs of the body, are not converted into other substances and stored away. Oxygen, as already stated (page 102), is not stored. The interval of storage may be long or short, depending upon the needs of the body. In the consumption of stored material the glycogen is used first, then as a rule the fat, and last of all the proteins.

Storage in the Food Canal. — Not until three or four hours have elapsed are all the nutrients, eaten at a single meal, digested and passed into the body proper. The undigested food is held in reserve, awaiting digestion, and

is only gradually absorbed as this process takes place. It may properly, on this account, be regarded as *stored material.* That such storage is of advantage is shown by the observed fact that substances which digest quickly (sugar, dextrin, "predigested foods," etc.) do not supply the needs of the body so well as do substances which, like starch and proteins, digest slowly. Even substances digesting quite slowly (greasy foods and pastry), since they can be stored longer in the food canal, may be of real advantage where, from hard work or exposure, the body requires a large supply of energy for some time. These "stay by" the laborer, giving him strength after the more easily digested foods have been used up. Storage by the food canal is limited chiefly to the stomach.

Regulation of the Food Supply to the Cells. — The storage of food materials is made to serve a second purpose in the plan of the body which is even more important than that of supplying nourishment to the cells during the intervals when no food is being taken. It is largely the means whereby the rate of supply of materials to the cells is regulated. The cells obtain their materials from the lymph, and the lymph is supplied from the blood. Should food substances, such as sugar, increase in the blood beyond a low per cent, they are converted into a form, like glycogen, in which they are held in reserve, or, for the time being, placed beyond the reach of the cells. When, however, the supply is reduced, the stored-up materials reënter the blood and again become available to the cells. By this means their rate of supply to the cells is practically constant.

We are now in a position to understand why carbohydrates, fats, and proteins are so well adapted to the needs of the body, while other substances, like alcohol, which

may also liberate energy, prove injurious. It is because foods are of such a chemical nature that they are adapted in all respects to the body plan of taking up and using materials, while the other substances are lacking in some particular.

Why Alcohol is not a Food. — If the passage of alcohol through the body is followed, it is seen, in the first place,

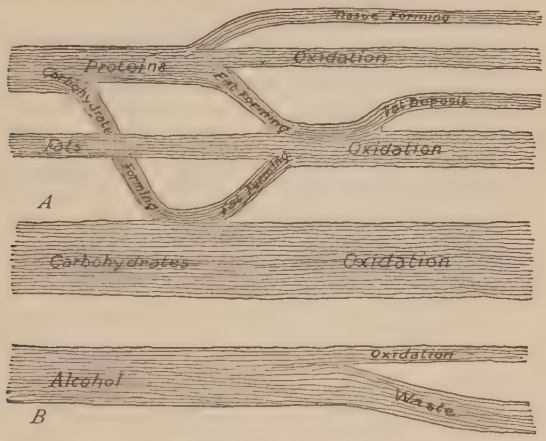

Fig. 80. — Diagrams illustrating the relation of nutrients and the non-relation of these to alcohol. *A*. Inter-relation and convertibility of proteins, fats, and carbohydrates (after Hall).

B. Diagram showing disposition of alcohol if this substance is taken in quantity corresponding to that of the nutrients (F. M. W.). The alcohol thrown off as waste is unoxidized and yields no energy.

that it is a simple liquid and undergoes no digestive change; and in the second place, that it is rapidly absorbed from the stomach in both weak and concentrated solutions. This introduces it quickly into the blood, and once there, it diffuses rapidly into the lymph and then into the cells. Since the body cannot store alcohol or convert it into some nutrient that can be stored (Fig. 80), *there is no way of*

regulating the amount that shall be present in the blood, or of supplying it to the cells as their needs require. They must take it in excess of their needs, regardless of the effect, at least until the organs of excretion can throw off the surplus as waste. Compared with protein, carbohydrates, or fats, alcohol is an *unmanageable* substance in the body. Attempting to use it as a food is as foolish as trying to burn gasolene or kerosene in an ordinary wood stove. It may be done to a limited extent, but is an exceedingly hazardous experiment. Not being adapted to the body method of using materials, alcohol cannot be classed as a food.

Assimilation. — Digestion, absorption, circulation, and storage of foods are the processes that finally make them available to the cells in the different parts of the body. There still remains another process for these materials to undergo before they serve their final purposes. This last process, known as *assimilation*, is the appropriation of the food material by the cell protoplasm. In a sense the storage of fat by connective tissue cells and of glycogen by the liver cells is assimilation. The term is limited, however, to the disposition of material with reference to its final use. Whether all the materials used by the cells actually become a part of the protoplasm is not known. It is known, however, that the cells are the places where most of the oxidations of the body occur and that materials taking part in these oxidations must, at least, come in close contact with the protoplasm. Assimilation, then, is the last event in a series of processes by which oxygen, food materials, and cell protoplasm are brought into close and *active* relations. The steps leading up to assimilation are shown in Table II.

TABLE II. The Passage of Materials to the Cells

Materials	Digestion	Absorption	Route to the General Circulation	Storage	Condition in the Blood
Proteins	Changed into proteoses and peptones by the action of the gastric and pancreatic juices.	In passing into the capillaries, the proteoses and peptones change into the proteins of the blood.	Through the portal vein to the liver and from there through the hepatic veins into the inferior vena cava.	Become a part of the protoplasm of all the cells.	As proteins in colloidal solution.
Fat	Changed into fatty acid, glycerine, and soluble soap by the bile and pancreatic juice.	In passing into the lacteals, the glycerine unites with the soluble soap and fatty acid to form the oil droplets of the blood.	Through the lacteals to the thoracic duct, by which it is emptied into the left subclavian vein.	As fat in the cells of connective tissue.	Chiefly as minute oil droplets.
Starch	Reduced to some of the different forms of sugar, as maltose, dextrose, etc.	Enters the capillaries as dextrose.	Through the portal vein, liver, hepatic veins, into inferior vena cava.	As glycogen chiefly by the liver, but to some extent by muscle cells.	As dextrose in solution.
Water	Undergoes no change.	Taken up by both the lacteals and the capillaries, but to the greater extent by the capillaries.	Both routes, but mostly by way of the liver.	Is not stored in the sense that energy foods are.	As the water which serves as a carrier of all the other constituents of the blood.
Common salt	Undergoes no change.	Taken up by the capillaries without undergoing apparent change.	By way of the portal vein, liver, and hepatic veins into inferior vena cava.	Not stored.	In solution.
Oxygen		Taken up by the capillaries at the lungs.	Already in the general circulation.	Is not stored.	United with the hemoglobin and to a small extent in solution in the plasma.

Tissue Enzymes. — The important part played by enzymes in the digestion of the food has suggested other uses for them in the body. It has been recently shown that many of the chemical changes in the tissues are in all probability due to the presence of enzymes. An illustration of what a tissue enzyme may do is seen in the changes which fat undergoes. In order for the body to use up its reserve fat, it must be transferred from the connective tissue cells, where it is stored, to the cells of the active tissues where it is to be used. This requires that it be reduced to the form of a solution and that it reënter the blood. In other words, it must be *redigested*. For bringing about these changes a substance identical in function with the steapsin of the pancreatic juice has been shown to exist in several of the tissues.

Although this subject is still under investigation, it may be stated with certainty that there are present in the tissues, enzymes that change dextrose to glycogen and *vice versa*, that break down and build up the proteins, and that aid in the oxidations at the cells. The necessity for such enzymes is quite apparent.

Summary. — The digested nutrients are taken up by the capillaries and the lymph vessels and transferred by two routes to the circulation. In passing from the alimentary canal into the circulation the more important of the foods undergo changes which adapt them to the needs of the body. Since materials are absorbed more rapidly than they are used, means are provided for storing them and for supplying them to the cells as their needs require. *Capability of storage is an essential quality of energy-yielding foods;* and substances, such as alcohol, which lack this quality are not adapted to the needs of the body. For causing the chemical changes that occur in the storage of foods, as well as the oxidations at the cells, the presence of active agents, or enzymes, is necessary.

Exercises. — 1. In what respects does the absorption of food materials from the alimentary canal differ from the absorption of a simple liquid by a solid?

2. In what different ways is the small intestine especially adapted to the work of absorption?

3. What are the parts of a villus? What are the lacteals? Account for the name.

4. What part is played by the capillaries and the lacteals in the work of absorption? How does their work differ?

5. What changes, if any, take place in water, common salt, fat, proteins, and carbohydrates during absorption?

6. What double purpose is served by the processes of digestion?

7. Trace the passage of proteins, fats, and carbohydrates from the small intestine into the general circulation.

8. What is the necessity for storing nutrients in the body? Why is it not also necessary to store up oxygen?

9. In what form and at what places is each of the principal nutrients stored?

10. How is the rate of supply of food to the cells regulated? Why is the body unable to regulate the supply of alcohol to the cells when this substance is taken?

11. Explain Fig. 80, page 189. What becomes of the alcohol if this is taken in any but very small quantities?

12. State the general purpose of enzymes in the body. Name the enzymes found in each of the digestive fluids. What ones are found in the tissues?

PRACTICAL WORK

Illustrate the ordinary meaning of the term "absorption" by bringing the end of a piece of crayon in contact with water, or a piece of blotting paper in contact with ink, noting the passage of the liquid into the crayon or the paper. Show how absorption from the food canal differs from this kind of absorption.

Show by a diagram similar to Fig. 77 the two routes by which the foods pass from the alimentary canal into the blood stream.

CHAPTER XVII

ENERGY SUPPLY OF THE BODY

If one stops taking food, it becomes difficult after a time for him to move about and to keep warm. These results show that food has some relation to the energy of the body, for motion and heat are forms of energy. The relation of oxygen to the supply of energy has already been discussed (Chapter X). We are now to inquire more fully into the energy supply of the body, and to consider those conditions which make necessary the introduction of both food and oxygen for this purpose.

Kinds of Bodily Energy. — The healthy body has at any time a considerable amount of *potential*, or reserve, energy, — energy which it is not using at the time, but which it is able to use as its needs require. When put to use, this energy is converted into such forms of *kinetic* energy[1] as are indicated by the different kinds of bodily power. These are as follows:

1. *Power of Motion.* — The body can move itself from place to place and it can give motion to things about it.

[1] Energy, which is defined as *the ability to do work*, or *to cause motion*, exists in two general types, or forms, known as kinetic energy and as potential energy. *Kinetic* energy is energy at work, or energy in the act of producing motion; while *potential* energy is reserve, or stored, energy. All moving bodies have kinetic energy, and all stationary bodies which have within them the *capability* of causing motion possess potential energy. A bent bow, a piece of stretched rubber, a suspended weight, the water above a mill dam, all have the capability of causing motion and all have potential energy. Examples of kinetic energy are found in the movements of machinery, in steam and electricity, in winds, and in currents of water. Kinetic is the active, and potential the inactive, form of energy.

2. *Heat Power.* — The body keeps itself warm and is able to communicate warmth to its surroundings.

3. *Nervous Power.* — Through the nervous system the body exercises the power of control over its different parts.

As motion, heat, and nervous power the body uses most of its energy.

The Source of Bodily Energy. — As already indicated, the energy of the body is supplied through the food and the oxygen. These contain energy in the potential form, which becomes kinetic (active) through their uniting with each other in the body. Somewhat as the power of the steam engine is derived from the combustion of fuel in the furnaces, the energy of the body is supplied through the oxidations at the cells. How the food and oxygen come to possess energy is seen by a study of the general methods by which energy is stored up and used.

Simple Methods of Storing Energy. — Energy is stored by converting the kinetic into the potential form. Two of the simplest ways of doing this are the following:

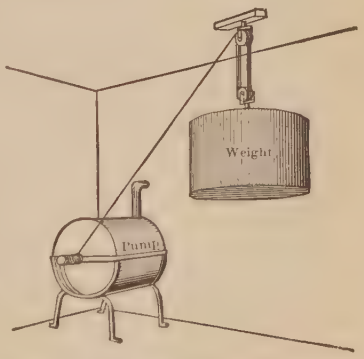

FIG. 81. — **Simple device** for storing energy through gravity.

1. *Storing of Energy through Gravity.* — On account of the attraction between the earth and all bodies upon the earth, the mere lifting of a weight puts it in a position where gravity can cause it to move (Fig. 81). As a consequence *the raising of bodies above the earth's surface is a means of storing energy* — the energy remaining stored until the

bodies fall. As they fall, the stored-up (potential) energy becomes kinetic and can be made to do work.

2. *Storing of Energy through Elasticity.* — Energy is stored also by doing work in opposition to elasticity, as in bending a bow or in winding a clock spring. The bending, twisting, stretching, or compressing of elastic substances puts them in a condition of *strain* which causes them to exert a pressure (called elastic force) that tends to restore them to their former condition. Energy stored by this means becomes active as the distorted or compressed substance returns to its former shape or volume.

These simple methods of storing energy will serve to illustrate the general principles upon which such storage depends:

1. To store energy, energy must be expended, or work done.

2. The work must be against some force, such as gravity or elasticity, which can undo the work, *i.e.*, bring about an effect opposite to that of the work.

3. The stored energy becomes active (kinetic) as the force through which the energy was stored undoes the work, or puts the substance upon which the work was done into its former condition (gravity causing bodies to fall, etc.).

These principles are further illustrated by the

Storing of Energy through Chemical Means. — A good example of storing energy by chemical means is that of decomposing water with electricity. If a current of electricity is passed through acidulated water in a suitable apparatus (Fig. 82), the water separates into its component gases, oxygen and hydrogen. These gases now have power (energy) which they did not possess before they were separated. The hydrogen will burn in the oxygen,

giving heat; and if the two gases are mixed in the right proportions and then ignited, they explode with violence. This energy was derived from the electricity. It was stored by *decomposing* the water.

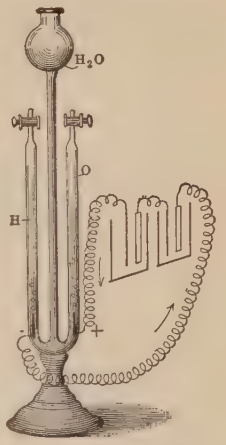

FIG. 82. — **Storing energy by chemical means.** Apparatus for decomposing water with electricity.

Energy is stored by chemical means by causing it to do work in opposition to the force of chemism, or chemical affinity. Instead of changing the form of bodies or moving them against gravity, it overcomes the force that causes atoms to unite and to hold together after they have united. Since in most cases the atoms on separating from any given combination unite at once to form other combinations, we may say that *energy is stored when strong chemical combinations are broken up and weak ones formed.* Energy stored by this means becomes active when the atoms of weak combinations unite to form combinations that are strong.[1]

How Plants store the Sun's Energy. — The earth's supply of energy comes from the sun. While much of this, after warming and lighting the earth's surface, is lost by radiation, a portion of it is stored up and retained. The sun's energy is stored both through the force of gravity[2]

[1] As the atoms of hydrogen and oxygen that make up the molecules of water separate, they unite with atoms of their own kind — the hydrogen with hydrogen and the oxygen with oxygen atoms. Since these combinations are weaker than those of the water molecules, energy is required to bring about the change. But when hydrogen burns in the oxygen, the change is from a weaker to a stronger combination. The stored-up energy is then given up or becomes active.

[2] In the evaporation of water, the energy of the sun is stored with reference to the force of gravity. In evaporating, water rises as a gas, or vapor, above the earth's

and by chemical means, the latter being the more important of the two methods. Plants supply the means for storing it chemically (Fig. 83). Attention has already been called to the fact (page 106) that growing plants are continually taking carbon dioxid into their leaves from the air. This they decompose, adding the carbon to compounds in their tissues and returning the oxygen to the air. It is found, however, that this process does not occur unless the plants are exposed to sunlight. The sunlight supplies the energy for overcoming the attraction between the atoms of oxygen and the atoms of carbon, while the plant itself serves as the instrument through which the sunlight acts. The energy for decomposing the carbon dioxid then comes from the sun, and through the decomposition of the carbon dioxid the sun's energy is stored — becomes potential. It remains stored until the carbon of the plant again unites with the oxygen of the air, as in combustion.

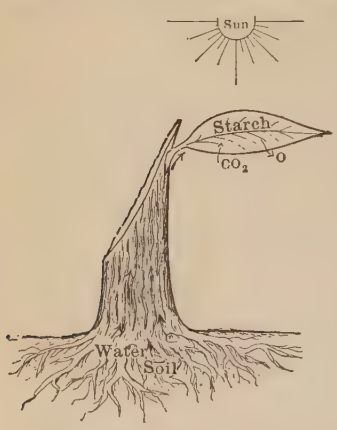

FIG. 83. — **Nature's device** for storing energy from the sun. See text.

The Sun's Energy in Food and Oxygen. — Food is derived directly or indirectly from plants and sustains the same relation to the oxygen of the air as do the plants themselves. (The elements in the food have an attraction for

surface, but on condensing into a liquid, it falls as rain. It then finds its way through streams back to the ocean. All water above the sea level is in such a position that gravity can act on it to cause motion, and it possesses, on this account, potential or stored-up energy. It is because of this energy that rapids and waterfalls are such important sources of power.

the oxygen, but are separated chemically from it.) On account of this relation they have potential energy — the energy derived through the plant from the sun. When a person eats the food and breathes the oxygen, this energy becomes the possession of the body. It is then converted into kinetic energy as the needs of the body require.

From the Sun to the Cells. — It thus appears that the body comes into possession of energy, and is able to use it, through a series of transferences and transformations that can be traced back to the sun.[1] Coming to the earth as kinetic energy, it is transformed into potential energy and stored in the compounds of plants and in the oxygen of the air. Through the food and the oxygen the potential energy is transferred to the cells of the body. Then by the uniting of the food and the oxygen at the cells (oxidation), the potential becomes kinetic energy and is

[1] Energy, like matter, can neither be created nor destroyed. It can, however, be transferred from one body to another and transformed from one form to another form. Whenever work is done, energy is transferred from the body doing the work, to the body upon which the work is done. During this process there may, or may not, be a transformation of energy. In turning a grindstone, kinetic energy is passed to the stone and used without transformation, but in winding a clock, the kinetic energy from the hand is transformed into potential energy in the clock spring. Then as the clock runs down this is retransformed into kinetic energy, causing the movements of the wheels.

Not only is kinetic transformed into potential energy and *vice versa*, but the different forms of kinetic energy (heat, light, electricity, sound, and mechanical motion) are readily transformed the one into the other. With suitable devices, mechanical motion can be changed into heat, sound, or electricity; heat into motion and light; and electricity into all the other forms of energy. These transformations are readily explained by the fact that the different varieties of kinetic energy are but different forms of motion (Fig. 84).

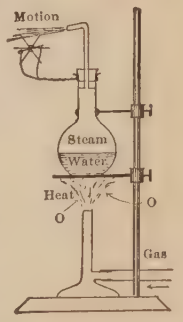

FIG. 84. — **Simple apparatus for illustrating transformation of energy. Potential energy is converted into heat and heat into motion.**

used by the body in doing its work. The phrase "Child of the Sun" has sometimes been applied to man to express his dependence upon the sun for his supply of energy.

Why Oxygen and Food are Both Necessary. — The necessity for introducing both oxygen and food into the body for the purpose of supplying energy is now apparent. The energy which is used in the body is not the energy of food alone. Nor is it the energy of oxygen alone. It belongs to both. It is due to their attraction for each other and their condition of separation. It cannot, therefore, become kinetic except through their union. To introduce one of these substances into the body without the other, would neither introduce the energy nor set it free. They must both be introduced into the body and there caused to unite.

Bodily Control of Energy. — A fact of importance in the supply of energy to the body is that the rate of transformation (changing of potential to kinetic) is just sufficient for its needs. It is easily seen that too rapid or too slow a rate would prove injurious. The oxidations at the cells are, therefore, under such control that the quantity of kinetic energy supplied to the body as a whole, and to the different organs, is proportional to the work that is done. This is attained, in part at least, through the ability of the body to store up the food materials and hold them in reserve until they are to be oxidized (page 188).

Animal Heat and Motion. — Most of the body's energy is expended as heat in keeping warm. It is estimated that as much as five sixths of the whole amount is used in this way. The proportion, however, varies with different persons and is not constant in the same individual during different seasons of the year. This heat is used in keeping the body at that temperature which is best suited to carry-

ing on the vital processes. All parts of the body, through oxidation, furnish heat. Active organs, however, such as the muscles, the brain, and the glands (especially the liver), furnish the larger share. The blood in its circulation serves as a *heat distributer* for the body and keeps the temperature about the same in all its parts (page 35).

Next to the production of heat, in the consumption of the body's energy, is the production of motion. This topic will be considered in the study of the muscular system (Chapter XXI).

Right Living and the Production of Heat. — Our ability to generate heat is an important item in its relation to the general health. A sudden chill may result in a number of derangements and is supposed to be a predisposing cause of *colds*. One's capacity for producing heat may be so low that he is unable to respond to a sudden demand for heat, as in going from a warm room into a cold one. As a consequence, the body is unable to protect itself against unavoidable exposures.

Impairment of the heat-producing capacity is brought about in many ways. Several diseases do this directly, or indirectly, to quite an extent. In health too great care in protecting the body from cold is the most potent cause of its impairment. Staying in rooms heated above a temperature of 70° F., wearing clothing unnecessarily heavy, and sleeping under an excess of bed clothes, all diminish the power of the body to produce heat. They accustom it to producing only a small amount, so that it does not receive sufficient of what might be called *heat-producing exercise*. Lack of physical exercise in the open air, as well as too much time spent in poorly lighted and ventilated rooms, tends also to reduce one's ability to produce heat. Moreover, since most of the heat of the body comes

from the union of oxygen and food materials at the cells, a lack of either of these will interfere with the production of heat.

Results of Exhaustion. — Through overwork, or excesses in pleasurable pursuits, one may make greater demands upon the energy of his body than it can properly supply. The resulting condition, known as *exhaustion*, is not only a matter of temporary inconvenience, but may through repetition lead to a serious impairment of the health. It should be noted, in this connection, that the energy of the body is spent in two general ways: first, in carrying on the vital processes; and second, in the performance of voluntary activities. Since, in all cases, there is a limit to one's energy, it is easily possible to expend so much in the voluntary activities that the amount left is not sufficient for the vital processes. This leads to various disturbances and, among other things, renders the body less able to supply itself with energy.

The Problem of Increasing One's Energy. — Since the energy supply is kept up through the food and the oxygen, it might be inferred that the introduction of these substances into the body in larger amounts would increase the energy at one's disposal. This does not necessarily follow. Oxidation at the cells is preceded by digestion, absorption, circulation, and assimilation. It is followed and influenced by the removal of wastes from the body. A careful study of the problem leads to the conclusion that while the energy supply to the body does depend upon the introduction of the proper amounts of food and oxygen, it also depends upon the efficiency of the vital processes. The maximum amount of energy may, therefore, be expected when the body is in a condition of perfect health. Hence, one desiring to increase the amount of his energy must

give attention to all those conditions that improve the health.

Effect of Stimulants on the Energy Supply. — In the effort to get out of the body as much as possible of work or of pleasure, various stimulants, such as alcohol, tobacco, and strong tea and coffee, have been used. Though these have the effect of giving a temporary feeling of strength and of enabling the individual in some instances to accomplish results which he could not otherwise have brought about, the general effect of their use is to lessen, rather than to increase, the sum total of bodily power. The student, for example, who drinks strong coffee in order to study late at night is able to command less energy on the day following. While enabling him to draw upon his reserve of nervous power for the time being, the coffee deprives him of sleep and needed rest.

The danger of stimulants, so far as energy is concerned, is this: they tend to exhaust the bodily reserve so that there is not sufficient left for properly running the vital processes. Evidences of their weakening effect are found in the feeling of discomfort and lassitude which result when stimulants to which the body has become accustomed are withdrawn. Not until one gets back his bodily reserve is he able to work normally and effectively. *Increase in bodily energy comes through health and not through the use of stimulants.*

Summary. — The body requires a continuous supply of energy. To obtain this supply, materials possessing potential, or stored-up, energy are introduced into it. The free oxygen of the air and the substances known as foods, on account of the chemical relations which they sustain to each other, contain potential energy and are utilized for supplying the body. So long as the foods are not oxidized, the energy remains in the potential form, but in the process of oxidation the potential energy is changed to kinetic energy and made to do the work of the body.

Exercises. — 1. In what different ways does the body use energy?

2. Show that a stone lying against the earth has no energy, while the same stone above the earth has energy.

3. How does potential energy differ from kinetic energy?

4. What kind of energy is possessed by a bent bow? By a revolving wheel? By a coiled spring? By the wind? By gunpowder?

5. How does decomposing water with electricity store energy?

6. Account for the energy possessed by the oxygen of the air and food substances.

7. Trace the energy supply of the body back to the sun.

8. Why must both oxygen and food be introduced into the body in order to supply it with energy?

9. How may overwork and overexercise diminish the energy supply of the body?

10. How may one increase the amount of his energy?

PRACTICAL WORK

Suggested Experiments. — 1. The change of kinetic into potential energy may be shown by stretching a piece of rubber, by lifting a weight, and by separating the armature from a magnet.

2. The change of potential into kinetic energy may be shown by letting weights fall to the ground, by releasing the end of a piece of stretched rubber, and by burning substances.

3. The change of one form of kinetic energy to another may be illustrated by rubbing together two pieces of wood until they are heated, by ringing a bell, and by causing motion in air or in water by heating them. If suitable apparatus is at hand, the transformation of electrical energy into heat, light, sound, and mechanical motion can easily be shown.

4. A weight connected by a cord with some small machine and made to run it, will help the pupil to grasp the general principles in the storage of energy through gravity. A vessel of water on a high support from which the water is siphoned on to a small water wheel will serve the same purpose.

5. The storing of energy by chemical means may be illustrated by decomposing potassium chlorate with heat or by decomposing water by means of a current of electricity.

6. Study the transfer of energy from the body to surrounding objects, as in moving substances and lifting weights.

Fill a half gallon jar two thirds full of water and carefully take the temperature with a chemical thermometer. Hold the hand in the water for four or five minutes and take the temperature again. Inference.

CHAPTER XVIII

GLANDS AND THE WORK OF EXCRETION

In our study so far we have been concerned mainly with the introduction of materials into the body. We are now to consider the removal of materials from the body. The structures most directly concerned in this work are known as

Glands. — As generally understood, glands are organs that prepare special liquids in the body and pour them out upon free surfaces. These liquids, known as *secretions*, are used for protecting exposed parts, lubricating surfaces that rub against each other, digesting food, and for other purposes. They differ widely in properties as well as in function, but are all alike in being composed chiefly of water. The water, in addition to being necessary to the work of particular fluids, serves in all cases as a carrier of solid substances which are dissolved in it.

General Structure of Glands. — While the various glands differ greatly in size, form, and purpose, they present striking similarities in structure. All glands contain the following parts:

1. Gland, or secreting, cells. These are *specialized* cells for the work of secretion and are the active agents in the work of the gland. They are usually cubical in shape.

2. A basement membrane. This is a thin, connective tissue support upon which the secreting cells rest.

3. A network of capillary and lymph vessels. These

penetrate the tissues immediately beneath the secreting cells.

4. A system of nerve fibers which terminate in the secreting cells and in the walls of the blood vessels passing to the glands.

These structures — secreting cells, basement membrane, capillary and lymph vessels, and nerve fibers — form the essential parts of all glands. The capillaries and the lymph vessels supply the secreting cells with fluid, and the nerves control their activities.

Kinds of Glands. — Glands differ from one another chiefly in the arrangement of their essential parts.[1] The most common plan is that of arranging the parts around a central cavity formed by the folding or pitting of an exposed surface. Many such glands are found in the mucous membrane, especially that lining the alimentary canal, and are most numerous in the stomach, where they supply the gastric juice. If these glands have the general form of tubes, they are called *tubular* glands; if sac-like in shape, they are called *saccular* glands. Both the tubular and the saccular glands may, by branching, form a great number of similar divisions which are connected with one another, and which communicate by a common opening with the place where the secretion is used. This forms a *compound* gland which, depending on the structure of the minute parts, may be either a *compound tubular* or a *compound saccular* gland. The larger of the compound saccular glands are also called *racemose* glands, on account of their having the general form of a cluster, or raceme, sim-

[1] The simplest arrangement of the parts of a gland is that where they are spread over a plain surface. This arrangement is found in serous membranes, such as the pleura and peritoneum. These membranes, however, are not called glands, but secreting surfaces.

ilar to that of a bunch of grapes. The general structure of the different kinds of glands is shown in Fig. 85.

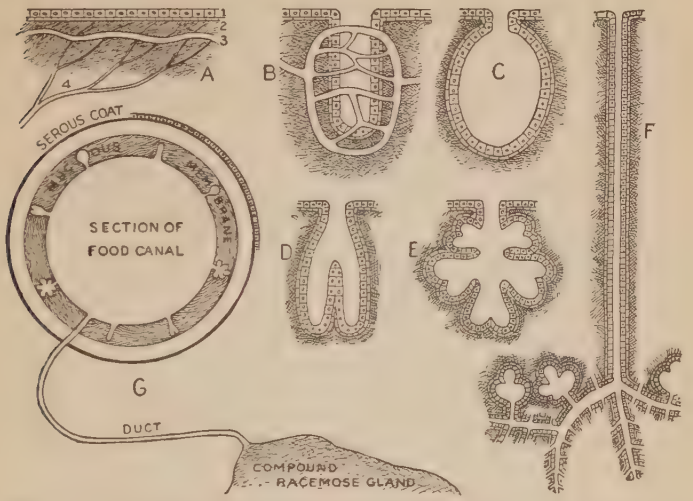

FIG. 85. — **Diagram illustrating evolution of glands.** *A.* Simple secreting surface. 1. Gland cells. 2. Basement membrane. 3. Blood vessel. 4. Nerve. *B.* Simple tubular gland. *C.* Simple saccular gland. *D.* Compound tubular gland. *E.* Compound saccular gland. *F.* A compound racemose gland with duct passing to a free surface. *G.* Relation of food canal to different forms of glands. The serous coat has a secreting surface.

Nature of the Secretory Process. — At one time the gland was regarded merely as a kind of filter which separated from the blood the ingredients found in its secretions. Recent study, however, of several facts relating to secretion has led to important modifications of this view. The secretions of many glands are known to contain substances that are not found in the blood, or, if present, are there in exceedingly small amounts. Then again the cells of certain glands have been found to undergo marked changes during the process of secretion. If, for example, the

cells of the pancreas be examined after a period of rest, they are found to contain small granular bodies. On the other hand, if they are examined after a period of activity, the granules have disappeared and the cells themselves have become smaller (Fig. 86). The granules have no doubt been used up in forming the secretion. These

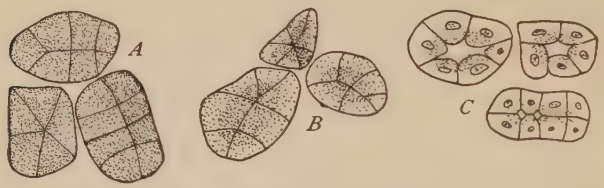

FIG. 86. — **Secreting cells from the pancreas** (after Langley). *A*. After a period of rest. *B*. After a short period of activity. *C*. After a period of prolonged activity. In *A* and *B* the nuclei are concealed by the granules that accumulate during the resting period.

and other facts have led to the conclusion that secretion is, in part, the separation of materials without change from the blood, and, in part, a process by which special substances are prepared and added to the secretion. According to this view the gland plays the double rôle of a *filtering apparatus* and of a *manufacturing organ*.

Kinds of Secretion. — In a general way all the liquids produced by glands may be considered as belonging to one or the other of two classes, known as the *useful* and the *useless* secretions. To the first class belong all the secretions that serve some purpose in the body, while the second includes all those liquids that are separated as waste from the blood. The first are usually called *true secretions*, or secretions proper, while the second are called *excretions*. The most important glands producing liquids of the first class are those of digestion (Chapter XIII).

Excretory Work of Glands. — The process of removing wastes from the body is called *excretion*. While in theory excretion may be regarded as a distinct physiological act, it is, in fact, leaving out the work of the lungs, but a phase of the work of glands. From the cells where they are formed, the waste materials pass into the lymph and from the lymph they find their way into the blood. They are removed from the blood by glands and then passed to the exterior of the body.

The Necessity for Excretion is found in the results attending oxidation and other chemical changes at the cells (page 101). Through these changes large quantities of materials are produced that can no longer take any part in the vital processes. They correspond to the ashes and gases of ordinary combustion and form wastes that must be removed. The most important of these substances, as already noted (page 104), are carbon dioxid, water, and urea.[1] A number of mineral salts are also to be included with the waste materials. Some of these are formed in the body, while others, like common salt, enter as a part of the food. They are solids, but, like the urea, leave the body dissolved in water.

Waste products, if left in the body, interfere with its work (some of them being poisons), and if allowed to accumulate, cause death. Their removal, therefore, is as important as the introduction of food and oxygen into the body. The most important of the excretory glands are

The Kidneys. — The kidneys are two bean-shaped glands, situated in the back and upper portion of the abdominal

[1] In the oxidations that occur in the body it is not supposed that the nutrients are immediately converted to carbon dioxid, water, and urea. On the other hand, it is held that their reduction takes place gradually, as the reduction of sugar by fermentation, and that the wastes leaving the body are but the "end products" and show only the final results.

cavity, one on each side of the spinal column. They weigh from four to six ounces each, and lie between the abdominal wall and the peritoneum. Two large arteries from the aorta, called the *renal arteries*, supply them with blood, and they are connected with the inferior vena cava by the *renal veins*. They remove from the blood an exceedingly complex liquid, called the *urine*, the principal constituents of which are water, salts of different kinds, coloring matter, and urea. The kidneys pass their secretion by two slender tubes, the *ureters*, to a reservoir called the *bladder* (Fig. 87).

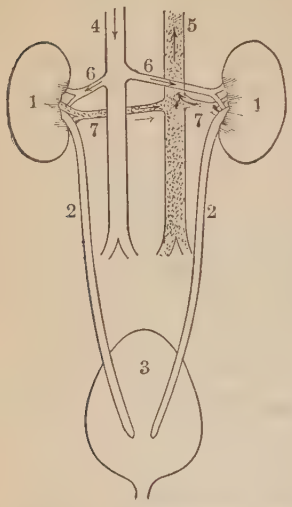

FIG. 87. — **Relations of the kidneys.** (Back view.) 1. The kidneys. 2. Ureters. 3. Bladder. 4. Aorta. 5. Inferior vena cava. 6. Renal arteries. 7. Renal veins.

Structure of the Kidneys. — Each kidney is a compound tubular gland and is composed chiefly of the parts concerned in secretion. The ureter serves as a duct for removing the secretion, while the blood supplies the materials from which the secretion is formed. On making a longitudinal section of the kidney, the upper end of the ureter is found to expand into a basin-like enlargement which is embedded in the concave side of the kidney. The cavity within this enlargement is called the *pelvis of the kidney*, and into it project a number of cone-shaped elevations from the kidney substance, called the *pyramids* (Fig. 88).

From the summits of the pyramids extend great numbers of very small tubes which, by branching, penetrate to

all parts of the kidneys. These are the *uriniferous tubules*, and they have their beginnings at the outer margin of the kidney in many small, rounded bodies called the *Malpighian capsules* (*A*, Fig. 88). Each capsule incloses a cluster of looped capillaries and connects with a single tubule (Fig. 89). From the capsule the tubule extends toward the con-

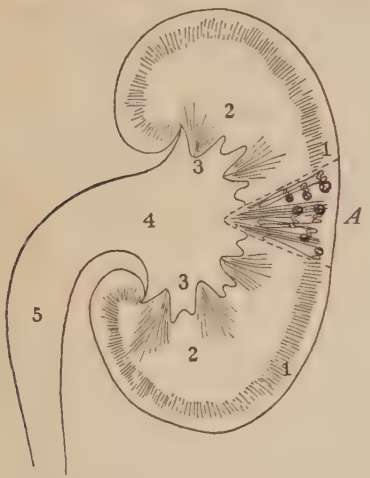

FIG. 88. — **Sectional view of kidney.** 1. Outer portion or cortex. 2. Medullary portion. 3. Pyramids. 4. Pelvis. 5. Ureter. *A*. Small section enlarged to show the tubules and their connection with the capsules.

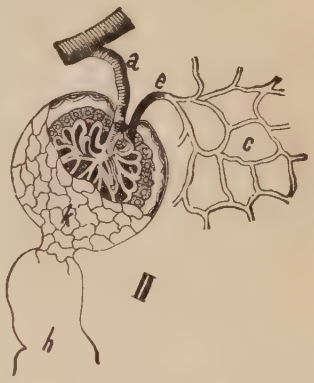

FIG. 89. — **Malpighian capsule** highly magnified (Landois). *a*. Small artery entering capsule and forming cluster of capillaries within. *e*. Small vein leaving capsule and branching into *c*, a second set of capillaries. *h*. Beginning of uriniferous tubule.

cave side of the kidney and, after uniting with similar tubules from other parts, finally terminates at the pyramid. Between its origin and termination, however, are several convolutions and one or more loops or turns. After passing a distance many times greater than from the surface to the center of the kidney, the tubule empties its contents into the expanded portion of the ureter.

The uriniferous tubules are lined with secreting cells. These differ greatly at different places, but they all rest upon a basement membrane and are well supplied with capillaries. These cells provide one means of separating wastes from the blood (Fig. 90).

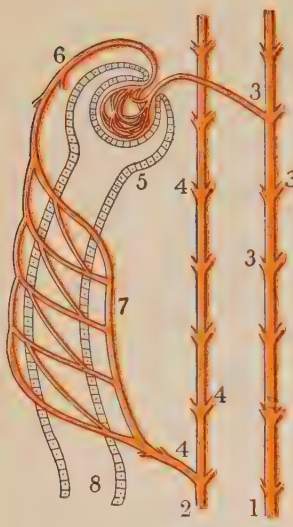

FIG. 90. — **Diagram illustrating renal circulation.** 1. Branch from renal artery. 2. Branch from renal vein. 3. Small artery branches, one of which enters a Malpighian capsule (5). 6. Small vein leaving the capsule and branching into the capillaries (7) which surround the uriniferous tubules. 4. Small veins which receive blood from the second set of capillaries. 8. Tubule showing lining of secreting cells.

Blood Supply to the Kidneys. — The method by which the kidneys do their work is suggested by the way in which the blood circulates through them. The renal artery entering each kidney divides into four branches and these send smaller divisions to all parts of the kidney. At the outer margin of the kidney, called the *cortex*, the blood is passed through *two sets of capillaries*. The first forms the clusters in the Malpighian capsules and receives the blood directly from the smallest arteries. The second forms a network around the uriniferous tubules and receives the blood which has passed from the capillary clusters into a system of small veins (Fig. 90). From the last set of capillaries the blood is passed into veins which leave the kidneys where the artery branches enter, uniting there to form the main renal veins.

Work of the Kidneys. — Why should the blood pass through two systems of capillaries in the kidneys? This is because the separation of waste is done in part by the Malpighian capsules and in part by the uriniferous tubules. Water and salts are removed chiefly at the capsules, while the remaining solid constituents of the urine pass through the secreting cells that line the tubules. It was formerly believed that the kidneys obtained their secretion by a process of filtration from the blood, but this belief has been gradually modified. The prevailing view now is that the processes of filtration and secretion are both carried on by the kidneys, — that the capillary clusters in the Malpighian bodies serve as delicate filters for the separation of water and salts, while the secreting cells of the tubules separate substances by the process of secretion.

On account of the large volume of blood passing through the kidneys this liquid is still a bright red color as it flows into the renal veins (Fig. 90). The kidney cells require oxygen, but the amount which they remove from the blood is not sufficient to affect its color noticeably. The blood in the renal veins, having given up most of its impurities and still retaining its oxygen, is considered the purest blood in the body.

Urea is the most abundant solid constituent of the urine and is the chief waste product arising from the oxidation of nitrogenous substances in the body. Although secreted by the cells lining the uriniferous tubules, it is not formed in the kidneys. The secreting cells simply separate it from the blood where it already exists. The muscles also have been suggested as a likely source of urea, for here the proteins are broken down in largest quantities; but the muscles produce little if any urea. Its production has been found to be the *work of the liver*. In the muscular tissue, and in the other tissues as well, the proteins are reduced to a lower order of compounds, such as the compounds of

ammonia, which pass into the blood and are then taken up by the liver. By the action of the liver cells these are converted into urea and this is turned back into the blood. From the blood the urea is separated by the secreting cells of the kidneys.

Work of the Liver. — The liver, already described as an organ of digestion (page 152), assists in the work of excretion both by changing waste nitrogenous compounds into urea and by removing from the blood the wastes found in the bile. While the chief work of the liver is perhaps not that of excretion, its functions may here be summarized. The liver is, first of all, a *manufacturing organ*, producing, as we have seen, three distinct products — bile, glycogen, and urea. On account of the nature of the urea and the bile, the liver is properly classed as an *excretory organ;* but in the formation of the glycogen it plays the part of a *storage organ.* Then, on account of the use made of the bile after it is passed into the food canal, the liver is also classed as a *digestive organ.* These different functions make of the liver an organ of the first importance.

Excretory Work of the Food Canal. — The glands connected with the food canal, other than the liver, while secreting liquids that aid in digestion, also separate waste materials from the blood. These are passed into the canal, whence they leave the body with the undigested portions of the food and the waste from the liver. Though the nature and quantity of the materials removed by these glands have not been fully determined, recent investigations have tended to enhance the importance attached to this mode of excretion.

The Perspiratory Glands. — The perspiratory, or sweat, glands are located in the skin. They belong to the type of simple tubular glands and are very numerous over the

entire surface of the body. A typical sweat gland consists of a tube which, starting at the surface of the cuticle, penetrates to the under portion of the true skin and there forms a ball-shaped coil. The coiled extremity, which forms the secreting portion, is lined with secreting cells and surrounded by a network of capillaries. The portion of the tube passing from the coil to the surface serves as a duct (Figs. 91 and 117).

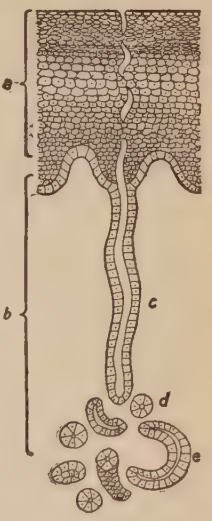

FIG. 91. — **Diagram of section through a sweat gland.** *a*. Outer layer of skin or cuticle. *b*. Dermis or true skin. *d*, *e*. Sections of the tube forming the coiled portion of the gland. *c*. Duct passing to the surface. The other structures of the skin not shown.

The sweat glands secrete a thin, colorless fluid, called *perspiration*, or sweat. This consists chiefly of water, but contains a small per cent of salts and of urea. The excretory work of these glands seems not to be so great as was formerly supposed, but they supplement in a practical way the work of the kidneys and, during diseases of these organs, show an increase in excretory function to a marked degree. The perspiration also aids in the regulation of the temperature of the body (Chapter XXIII).

Excretory Work of the Lungs. — While the lungs cannot be regarded as glands, they do a work in the removal of waste from the body which must be considered in the general process of excretion. They are especially adapted to the removal of gaseous substances from the blood, and it is through them that most of the carbon dioxid leaves the body. The lungs

remove also a considerable quantity of water. This is of course in the gaseous form, being known as water vapor.

Ductless Glands and Internal Secretion. — Midway in function between the glands that secrete useful liquids and those that remove waste materials from the blood is a class of bodies, found at various places, known as the *ductless glands*. They are so named from their having the general form of glands and from the fact that they have no external openings or ducts. They prepare special materials, called *hormones*, which are passed into the blood and which exert some beneficial effect either upon the blood or upon the tissues through which the blood circulates. The most important of the ductless glands are the thyroid gland, located in the neck; the suprarenal bodies, situated one just over each kidney; and the thymus gland, a temporary gland in the upper part of the chest. The spleen and the lymphatic glands (page 65) are also classed with the ductless glands. The liver, the pancreas, and (according to some authorities) the kidneys, in addition to their external secretions, produce materials that pass into the blood. They perform in this way a function like that of the ductless glands. The work of glands in preparing substances that enter the blood is known as *internal secretion*.

Quantity of Excretory Products. — If the weight of the normal body be taken at intervals, after growth has been attained, there will be found to be practically no gain or loss from time to time. This shows that materials are leaving the body as fast as they enter and that the tissues are being torn down as fast as they are built up. It also shows that substances do not remain in the body *permanently*, but only so long perhaps as is necessary for them to give up their energy, or serve some additional purpose in the ever changing protoplasm. The excretory organs then remove from the body a quantity of material that is equal in weight to the materials absorbed by the organs of digestion and respiration. This is estimated for the average individual to be about seven pounds daily. The passage of waste from the body is summarized in Table III.

TABLE III. The Passage of Waste Materials from the Body

Materials	State	How formed in the Body	Condition in the Blood	How removed from the Blood
Carbon dioxid	Gas	By the oxidation of the carbon of proteins, carbohydrates, and fats.	Dissolved in the plasma and in loose combination with salts in the blood.	Separated from the blood at the alveoli of the lungs and then forced through the air passages into the atmosphere.
Urea	Solid	By the oxidation in the liver of nitrogenous compounds.	Dissolved in the plasma.	Removed by the uriniferous tubules of the kidneys and to a small extent by the perspiratory glands.
Water	Liquid	By the oxidation of the hydrogen of proteins, carbohydrates, and fats. Amount formed in the body is small.	As water.	Removed by all the organs of excretion, but in the largest quantities by the kidneys and the skin.
Salts	Solid		Dissolved in the plasma.	By the kidneys, liver, and skin.

RIGHT LIVING AND WASTE REMOVAL

The separation of wastes from the body has such a close relation to the health that all conditions affecting it should receive the most careful attention. Their retention beyond the time when they should be discharged undoubtedly does harm and is the cause of many bodily disorders.

Value of Water. — As a rule the work of excretion is aided by drinking *freely* of pure water. As water is the natural dissolver and transporter of materials in the body, it is generally conceded by hygienists and physicians that the taking of plenty of water is a healthful practice. People do not as a rule drink a sufficient amount of water, about three pints per day being required by the average adult, in addition to that contained in the food. Most of the water should, of course, be taken between meals, although the sipping of a small amount during meals does not interfere with digestion. As stated elsewhere, the taking of a cup of water on retiring at night and again on rising in the morning is very generally recommended.

Protection of Kidneys and Liver. — The kidneys and liver are closely related in their work and in many instances are injured or benefited by the same causes. Both, as already stated (page 128), are liable to injury from an *excess of protein food*, especially meats, and also by a condition of inactivity of the bowels (page 174). The free use of alcohol also has an injurious effect on both of these organs.[1] On the other hand, increasing the activity of the skin has a beneficial effect upon them, especially

[1] Alcohol, if used in considerable quantity, leads to cirrhosis of the liver and Bright's disease of the kidneys, both very dangerous diseases. Dr. William Osler in his treatise, *The Practice of Medicine*, states that alcohol is the chief cause of cirrhosis of the liver. Dr. T. N. Bogart, specialist in kidney diseases, asserts that one third of all the cases of Bright's disease coming under his observation are caused by alcohol.

the kidneys. Exercise and bathing, which tend to make the skin more active, are valuable aids both in ridding the body of impurities and in lessening the work of the other excretory organs. One having a disease of the kidneys, however, needs to exercise great care in bathing on account of the bad results which follow getting chilled.

Special Care after Certain Diseases. — Certain diseases, as measles, diphtheria, scarlet fever, and typhoid fever, sometimes have the effect of weakening the kidneys (and other vital organs) and of starting disease in them. When this occurs it is usually the result of exposure or of over-exertion while the body is in a weakened condition. Severe chilling at such a time, by driving blood from the surface to the parts within, often causes inflammation of the kidneys. On recovering from any wasting disease one should exercise great caution both in resuming his regular work and in exposing his body to wet or cold.

Misunderstood Symptoms. — Pains in the small of the back, an increase in the secretions of the kidneys, and a sediment in the urine very naturally suggest some disorder of the kidneys. It is a fact, however, that these symptoms have little or no relation to the state of the kidneys and may occur when the kidneys are in a perfectly healthy condition. The kidneys are not located in the small of the back, but above this place, so that pains in this region are evidently not from the kidneys, while the increase in the flow of the urine may arise from a number of causes, one of which is an increase of certain waste products passed into the blood. The symptoms referred to are frequently the results of nervous exhaustion, resulting from overstudy, worry, eye strain, or some other condition that overtaxes the nervous system. When this is the case, relief is obtained through resting the nerves. Actual

disease of the kidneys can only be determined through a chemical and microscopic examination of the urine. To resort to some patent medicine for kidney trouble without knowing that such trouble exists, as is sometimes done, is both foolish and unhygienic.

Alcoholic Beverages and the Elimination of Waste. — Causing as it does such serious diseases as cirrhosis of the liver and Bright's disease of the kidneys (footnote, page 218), alcohol will greatly interfere in this way with the elimination of waste. There is also evidence to the effect that it interferes with waste elimination before the stage is reached of causing disease of these organs. Researches have shown that alcohol increases the amount of uric acid in the body and decreases the amount of urea found in the urine. The conclusion to be drawn is that alcohol interferes in some way with the change of the harmful uric acid into the comparatively harmless urea — an interference which in some instances results in great harm. It has also been shown that malted liquors, such as beer and ale, contain substances which, like the caffein of tea and coffee (page 179), are readily converted into uric acid.[1] Wines contain acids which may also act injuriously. The harm which such substances do is, of course, additional to that caused by the alcohol.

Summary. — As a result of the oxidations and other changes at the cells, substances are produced that can no longer serve a purpose in the body. They are of the nature of waste, and their continuous removal from the body is as necessary to the maintenance of life as the introduction of food and oxygen. The organs whose work it is to remove the waste, excepting the lungs, are glands; and the material which they remove are of the nature of secretions. From the cells, the waste passes through the lymph in the blood. From the blood it is separated by the excretory organs and passed to the exterior of the body.

Exercises. — 1. What general purposes are served by the glands in the body?

[1] Hall, *The Purin Bodies*.

2. What are the parts common to all glands? What purpose is served by each of these parts?

3. How do tubular glands differ in structure from saccular glands? What is a racemose gland? Why so called?

4. Describe the nature of the secretory process.

5. What conditions render necessary the formation of waste materials in the body? Why must these be removed?

6. How do the waste materials get from the cells to the organs of excretion?

7. Show by a drawing the connections of the kidneys with the large blood vessels and the bladder. Name parts of drawing.

8. In what do the uriniferous tubes have their beginning? In what do they terminate? With what are they lined?

9. Why should the blood pass through two sets of capillaries in the kidneys?

10. Bright's disease of the kidneys affects the uriniferous tubes and interferes with their work. What impurity is then left in the blood?

11. Trace water and salts from the Malpighian capsules to the bladder, naming parts through which they pass.

12. Trace carbon dioxid from the cells to the outside atmosphere.

13. How does the quantity of material introduced into the body compare with that which is removed by the organs of excretion?

14. Name two ways of lessening the work of the kidneys.

15. Why is the drinking of plenty of pure water a healthful practice?

PRACTICAL WORK

To suggest the Double Work of Glands. — Prepare a simple filter by fitting a piece of porous paper into a glass funnel. Through this pass pure water and also water having salt dissolved in it and containing some sediment, as sand. The water and the dissolved salt pass through, while the sediment remains on the filter. Now substitute a fresh piece of paper in the funnel and drop on its surface a little solid coloring matter, such as cochineal. Again pass the liquid through the funnel. This time it comes through colored, the color being added by the filter. Compare the filter and materials filtered to the gland and the materials concerned in secretion (blood, the liquid secreted, substances added by the gland, etc.).

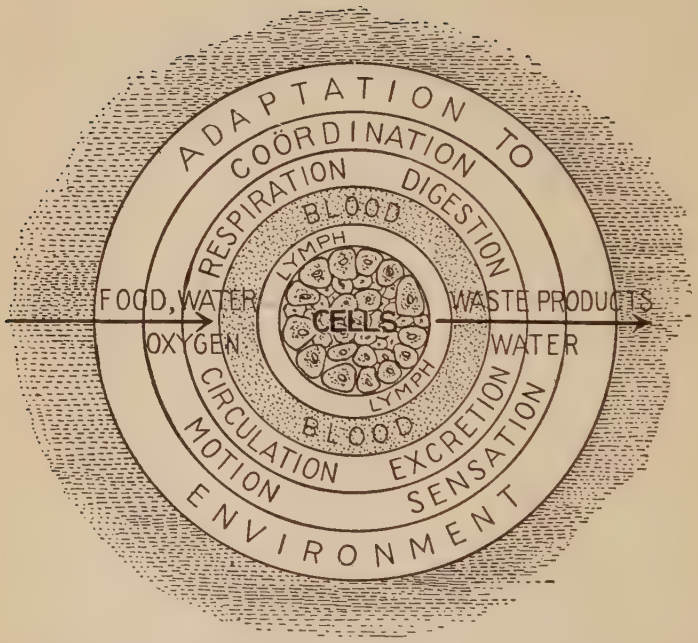

Fig. 92. — The physiological scheme. Diagram suggesting the essential relation of the bodily activities. See Summary of Part I, page 223, and Summary of Part II, page 416.

SUMMARY OF PART I

The body is an organization of different kinds of cells; it grows through the growth and reproduction of these cells; and its life as a whole is maintained by providing such conditions as will enable the cells to keep alive. Of chief importance in the work of the body is a nutrient fluid which supplies the cells with food and oxygen and relieves them of waste. A moving portion of this fluid, called the blood, serves as a transporting agent, while another portion, called the lymph, passes the materials between the blood and the cells. Through their effects upon the blood and the lymph, the organs of circulation, respiration, digestion, and excretion minister in different ways to the cells, and aid in keeping them alive. By their combined action two distinct movements are kept up in the body, as follows:

1. An *inward* movement which carries materials from the outside of the body toward the cells.

2. An *outward* movement which carries materials from the cells to the outside of the body.

Passing *inward* are the oxygen and food materials *in a condition to unite with each other* and thereby change their potential into kinetic energy. Passing *outward* are the oxygen and the elements that formed the food materials *after having united* at the cells and liberated their energy.

As a final and all-important result, there is kept up a *continuous series of chemical changes* in the cells. These liberate the energy, provide special substances needed by the cells, and preserve the life of the body (Fig. 92).

In the chapters which follow, we are to consider the problem of adjusting the body to and of bringing it into proper relations with its surroundings.

PART II: EXTERNAL WORK—MOTION, COÖRDINATION, SENSATION, ETC.

CHAPTER XIX

THE SKELETON

One necessary means of establishing proper relations between the body and its surroundings is *motion*.[1] Not only can the body move itself from place to place, but it is able to move surrounding objects as well. In the production of motion three important systems are employed — the muscular system, the nervous system, and a system of mechanical devices which are found mainly in the skeleton. The muscular system supplies the energy for operating the mechanical devices, while the nervous system controls the movements.[2] Although the skeleton serves internal purposes, such as giving shape to the body and protecting certain organs, its main use is external — that of an aid to motion with reference to things outside.

[1] Review "Purpose of the Body Organization," page 18.

[2] In the production of motion in the body, as well as in the production of any kind of *purposeful* motion outside of the body, three conditions must be fulfilled. There is required, in the first place, a mechanical device or machine which is so constructed as to produce a certain kind of motion. In the second place, energy is needed to operate this device. And, finally, there must be some controlling force by means of which the motion is made to accomplish definite results. The driving of a horse hitched to a wagon will illustrate these conditions. The wagon is the mechanical device, the horse furnishes the energy, and the driver supplies the controlling force. In this, as in most cases, the machinery, the source of energy, and the controlling force are disconnected except when at work; but in the body all three occur together in the same structure.

Skeleton Tissues. — The tissues employed in the construction of the skeleton are the osseous, the cartilaginous, and the connective tissues. These are known as the supporting tissues of the body. They form the bones, supply the elastic pads at the ends of the bones, and furnish strong bands, called ligaments, for fastening the bones together. The skeleton forms about 16 per cent of the weight of the body. Its tissues, being of a more durable nature than the rest of the body, do not so readily decay. Especially is this true of the osseous tissue, which may be preserved indefinitely, after removal from the body, by simply keeping it dry.

The Bones. — The separate units, or parts, of which the skeleton is constructed are called bones. They are the hard structures that can be felt in all parts of the body, and they comprise nearly the entire amount of material found in the prepared skeleton. As usually estimated, the bones are 206 in number. They vary greatly in size and shape in different parts of the body.

Composition and Properties of Bones. — The most noticeable and important properties of the bones are those of hardness, stiffness, and toughness. Upon these properties the uses of the bones depend. These properties may, in turn, be shown to depend upon the presence in osseous tissue of two essentially different kinds of substance, known as the *animal matter* and the *mineral matter*. If a bone is soaked in an acid, the mineral matter is dissolved out, and as a result it loses its properties of hardness and stiffness. (See Practical Work.) This is because the mineral matter supplies these properties, being composed of substances which are hard and closely resemble certain kinds of rock. The chief materials forming the mineral matter are calcium phosphate and calcium carbonate.

On the other hand, burning a bone destroys the animal matter. When this is done the bone loses its toughness, and becomes quite brittle. The property of toughness is, therefore, supplied by the animal matter. This consists mainly of a substance called *ossein*, which may be dissolved out of the bones by boiling them. Separated from the bones it is known as *gelatine*. The blood vessels and nerves in the bones, and the protoplasm of the bone cells, are also counted in with the animal matter.

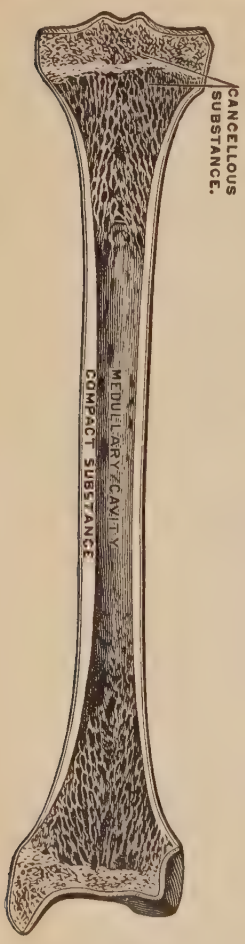

FIG. 93. — **Section of a long bone** (*tibia*), showing the gross structure.

If a dry bone from a full-grown, but not old, animal be weighed before and after being burned, it is found to lose about one third of its weight. From this we may conclude that about one third of the bone by weight is animal matter and two thirds is mineral matter. This proportion, however, varies with age, the mineral matter increasing with advance of years.

Gross Structure of Bones. — The gross structure of the bones is best learned by studying both dry and fresh specimens. (See Practical Work.) The ends of the bones are capped by a layer of smooth, elastic cartilage, while all the remaining surface is covered by a rather dense sheath of connective tissue, called the *periosteum*. Usually the central part

of the long bones is hollow, being filled with a fatty substance known as the *yellow marrow*. Around the marrow cavity the bone is very dense and compact, but most of the material forming the ends is porous and spongy. These materials are usually referred to as the *compact substance* and the *cancellous*, or *spongy, substance* of the bones (Fig. 93).

The arrangement of the compact and spongy substance varies with the different bones. In the short bones (wrist and ankle bones, vertebræ, etc.) and also in the flat bones (skull bones, ribs, shoulder blades, etc.) there is no cavity for the yellow marrow, all of the interior space being filled with the spongy substance. The spaces in the spongy substance are filled with a reddish substance, called *red marrow*. This has to do with the formation of red corpuscles for the blood (page 29).

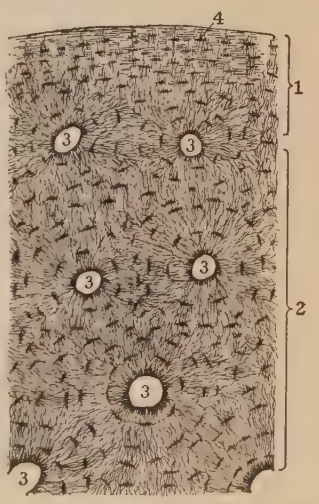

FIG. 94. — **Cross section of bone showing minute structure.** Magnified. 1. Surface layer of bone. 2. Deeper portion. 3. Haversian canals from which pass the canaliculi. 4. A lacuna. Observe arrangement of lacunæ at surface and in deeper portion.

Minute Structure of Bone. — A microscopic examination of a thin slice of bone taken from the compact substance shows this to be porous as well as the spongy substance. Two kinds of small channels are found running through it in different directions, known as the Haversian canals and the canaliculi (Fig. 94). These serve the general purpose of distributing nourishment through the bone. The *Haversian canals* are larger

than the canaliculi and contain small nerves and blood vessels. They run lengthwise through the bone. The canaliculi are channels for conveying lymph to the bone cells. They pass from the canals at right angles and connect with little spaces in the bone, called lacunæ (Fig. 94), in which the bone cells lie.

FIG. 95. — **Bone cell** removed from the lacuna and very highly magnified. (From Quain's *Anatomy*.)

The bone cell is a soft body with a nucleus (Fig. 95). Its work is to add mineral matter to the bone and thus to supply the properties of hardness and stiffness. However, it is not hard itself, as we might suppose.

Plan and Purpose of the Skeleton. — The framework of the body is such as to adapt it to a *movable* structure. Obviously the different parts of the body cannot be secured to a foundation, as are those of a stationary building, but must be arranged after a plan that is conducive to motion. A moving structure, as a wagon or a bicycle, has within it some strong central part to which the remainder is joined. The same is true of the skeleton. That part to which the others are attached is a long, bony axis, known as the *spinal column*. Certain parts, as the ribs and the skull, are attached directly to the spinal column, while others are attached indirectly to it. The arrangement of all the parts is such that the spinal column is made the central, cohering portion of the skeleton and also of the whole body. Besides this general arrangement of the parts of the skeleton, there is such a grouping of bones in each division as will enable them to serve definite purposes — to form mechanical devices for special movements in some cases; in others to support or protect important organs. We shall now consider the more important of the bone groups.

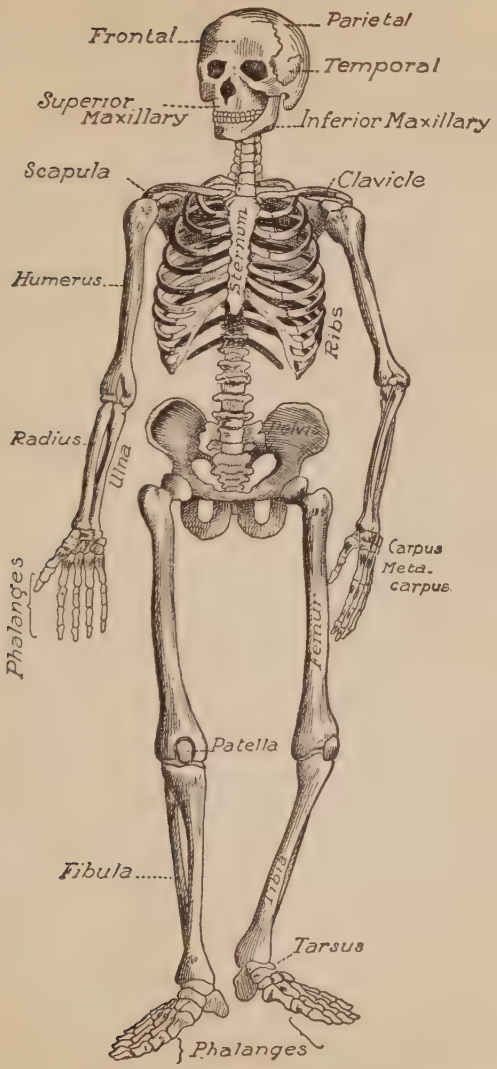

FIG. 96. — **The human skeleton.**

Bone Groups. — On account of the close relation between the bones of the same group, they cannot profitably be studied as individual bones, but each must be considered as a part of the group to which it belongs. By first making out the relation of a given bone to its group, its value to the whole body can be determined. The most important of the groups of bones are as follows:

1. *The Spinal Column.* — This group consists of twenty-four similarly shaped bones, placed one above the other, called the *vertebræ*, and two bones found below the vertebræ, known as the sacrum and the coccyx (Fig. 97). These twenty-six bones supply the central axis of the body, support the head and upper extremities, and inclose and protect the spinal cord.

The upper seven vertebræ form the neck and are called the *cervical* vertebræ. They are smaller and have greater freedom of motion than the others. The first and second cervical vertebræ, known as the *atlas* and the *axis*, are specially modified to form a support for the head and provide for its movements. The head rests upon the atlas, forming with it a hinge joint (used in nodding to indicate "yes"); and the atlas turns upon an upward projection of the axis forming a pivot joint (used in shaking the head to indicate "no").

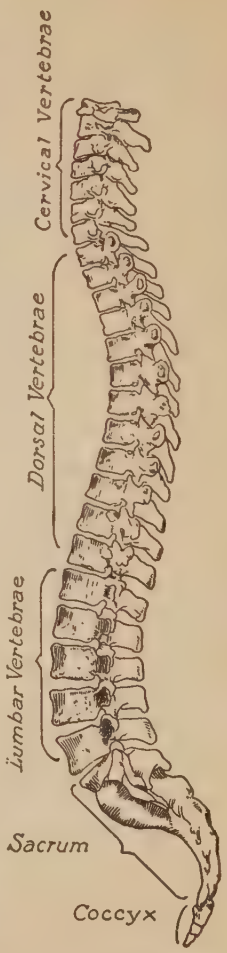

FIG. 97. — **The spinal column.**

The next twelve vertebræ, in order below the cervical, are known as the *thoracic* vertebræ. They form the back part of the framework of the thorax and have little freedom of motion. The five vertebræ below the thoracic are known as the *lumbar* vertebræ. These bones are large and strong and admit of considerable motion. Below the last lumbar vertebra is a wedge-shaped bone which has the appearance of five vertebræ fused together. This bone, known as the *sacrum*, connects with the large bones which form the pelvic girdle. Attached to the lower end of the sacrum is a group of from two to four small vertebræ, more or less fused, called the *coccyx*.

The Joining of the Vertebræ. — A typical vertebra consists of a heavy, disk-shaped portion in front, called the *body*, which is connected

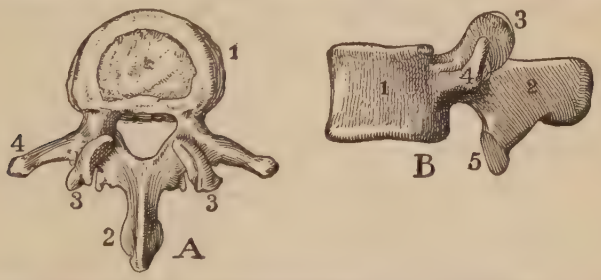

FIG. 98. — **Two views of a lumbar vertebra.** *A.* From above. *B.* From the side. 1. Body. 2, 3, 4, 5. Projections from the neural arch.

with a ring-like portion behind, called the *neural arch*. The body and the neural arch together encircle a round opening which is a part of the canal that contains the spinal cord (Fig. 98). From the neural arch are seven bony projections, or processes, three of which serve for the attachment of muscles and ligaments, while the other four, two above and two below, are for the interlocking of the vertebræ with each other. The separate vertebræ are joined together in the spinal column, as follows:

a. Between the bodies of adjacent vertebræ are disks of elastic cartilage. Each disk is about one fourth of an inch thick and is grown

tight onto the face of the vertebra above and also onto the face of the vertebra below. By means of these disks a very close connection is secured between the vertebræ on the front side of the column.

b. On the back of the column, the downward projections from the neural arch of each vertebra above fit into depressions found in the neural arch of the vertebra below. This *interlocking* of the vertebræ, which is most marked in the lumbar region, strengthens greatly the back portion of the column.

c. To further secure one bone upon the other, numerous ligaments pass from vertebra to vertebra on all sides of the column.

2. *The Skull.* — The skull is formed by the close union of twenty-two irregular bones. These fall naturally into two subgroups — the cranium and the face (Fig. 99). The *cranium* consists of eight thin, curved bones which inclose the space, called the *cranial cavity*, that holds the brain. The *face group*, consisting of fourteen bones, provides cavities and supports for the different organs of the face, and supplies a movable part (the inferior maxillary) which, with the bones above (superior maxillary), forms the machine for masticating the food.

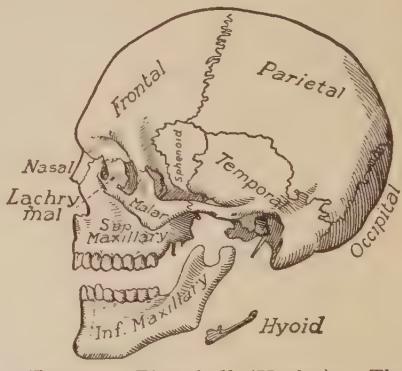

FIG. 99. — **The skull** (Huxley). The illustration shows most of the bones of the skull.

3. *The Thorax.* — This group contains twenty-four bones of similar form, called *ribs*, and a straight flat bone, called the *sternum*, or breastbone (Fig. 100). The ribs connect with the spinal column behind, and all but the two lowest ones connect with the sternum in front, and, by so doing, inclose the thoracic cavity.

The bones of the thorax form a mechanical device, or machine, for breathing. The ribs are so arranged that the volume of the thorax is increased by elevating them and diminished by depressing them, enabling the air to be forced into and out of the lungs.

4. *The Shoulder and Pelvic Girdles.* — These groups form two bony supports — one at the upper and the other at the lower portion of the trunk — which serve for the attachment of the arms and legs (Fig. 100). The *shoulder girdle* is formed by four bones — two clavicles, or collar bones, and two scapulæ, or shoulder blades. The clavicle on either side connects with the upper end of the sternum and serves as a *brace* for the shoulder, while the scapula forms a socket for the humerus (the large bone of the arm) and supplies many places for the attachment of muscles.

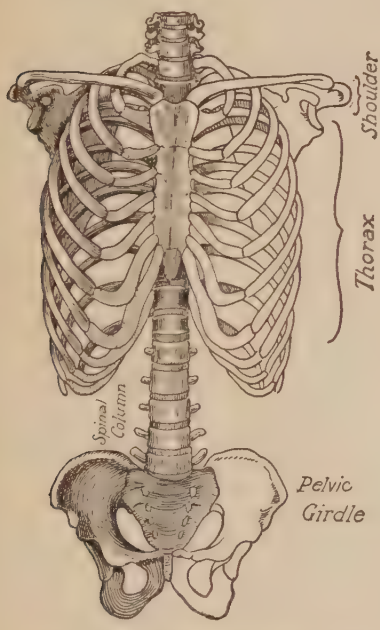

FIG. 100. — **Bone groups of trunk.**

The *pelvic girdle* consists of two large bones of irregular shape, called the *innominate* bones. They connect behind with the sacrum and in front they connect, through a small pad of cartilage, with each other. On the inside of the girdle is a smooth, basin-shaped support for the contents of the abdomen, but on the outside the bones are rough

and irregular and provide many places for the attachment of muscles and ligaments. Each innominate bone has a deep, round socket into which the end of the femur (the long bone of the leg) accurately fits.

5. *The Arm and Hand Groups.* — A long bone, the *humerus*, connects the arm with the shoulder and gives form to the upper arm. In the forearm are two bones, the *radius* and the *ulna*, which connect at one end with the humerus and at the other with the bones of the wrist (Fig. 101).

A group of eight small, round bones is found in the wrist, known as the *carpal* bones. These are arranged in two rows and are movable upon one another. Five straight bones, the *metacarpals*, connect with the wrist bones and form the framework for the palm of the hand. Attached to the metacarpals are the bones of the fingers and thumb. These form an interesting group of fourteen bones, called the *phalanges of the fingers* (Fig. 101).

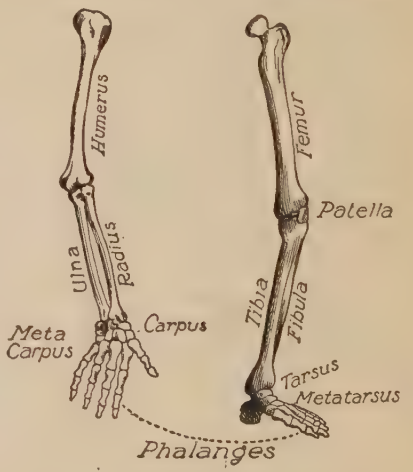

FIG. 101. — **Bone groups of arm and leg.**

The bones of the hand provide a mechanical device, or machine, for grasping, and the arm serves as a device for moving this grasping machine from place to place. The work of the arm, in this respect, is not unlike that of a revolving crane upon the end of which is a grab-hook. The hand without the arm to move it about would be of little use.

6. *The Leg and Foot Groups.* — These correspond in form and arrangement to the bones of the arm and hand. Since, however, the leg and foot are used for purposes different from those of the arm and hand, certain differences in structure are to be found. The *patella*, or kneepan, has no corresponding bone in the arm; and the *carpus*, or ankle, which corresponds to the wrist, contains seven instead of eight bones. The bones of the foot and toes are the same in number as those of the hand and fingers, but they differ greatly in size and form and have less freedom of motion. The *femur*, which gives form to the thigh, is the longest bone of the body. The *tibia*, or shin bone, and the *fibula*, the slender bone by its side, give form to the lower part of the leg (Fig. 101).

The legs are mechanical devices (walking machines) for moving the body from place to place. The feet serve both as supports for the body and as levers for pushing the body forward. By their attachment to the legs they may be placed in all necessary positions for supporting and moving the body.

The prepared skeleton (Fig. 97) shows each of the bone groups where it belongs.

Adaptation to Special Needs. — When any single bone is studied in its relation to the other members of the group to which it belongs or with particular reference to its purpose in the body, its adaptation to some special place or use is at once apparent. Each bone serves some special purpose, and to this purpose it is adapted by its form and structure. Long bones, like the humerus and femur, are suited to giving strength, form, and stiffness to certain parts, while irregular bones, like the vertebræ and the pelvic bones, are fitted for supporting and protecting organs. Others, like the wrist and ear bones, make possible a peculiar kind of motion, and still others, like the ribs, are adapted to more than one purpose. The vast differences in shape, size, structure, and surface among the various bones are but the conditions that adapt them to particular forms of service in the body.

ARTICULATIONS

Any place in the body where two or more bones meet is called an articulation, or joint. At the place of meeting the bones are firmly attached to each other, thereby securing the necessary coherence of the skeleton. The large number of bones, and consequently of articulations, are necessary for the different movements of the body and also on account of the manner in which the skeleton develops, or grows. Articulations are classed with reference to their freedom of motion, as *movable*, *slightly movable*, and *immovable* articulations.

Most of the *immovable* articulations are found in the skull. Here irregular, tooth-like projections from the different bones enable them to interlock with one another, while they are held firmly together by a thin layer of connective tissue. The wavy lines formed by articulations of this kind are called *sutures* (Fig. 99).

The best examples of joints that are *slightly*, but not freely, *movable* are found in the front of the spinal column. The cartilaginous pads between the vertebræ permit, by their elasticity, of a slight bending of the column in different directions. These movements are caused, not by one bone gliding over another, but by compressions and extensions of the cartilage. Between the vertebræ in the back of the spinal column, however, there is a slight movement of the bone surfaces upon one another.

Structure of the Movable Joints. — By far the most numerous and important of the joints are those that are freely movable. Such joints are strongly constructed and endure great strain without dislocation, and yet their parts move over each other easily and without friction. The ends of the bones are usually enlarged and have specially formed

projections or depressions which fit into corresponding depressions or elevations on the bones with which they articulate. In addition to this the articular surfaces are quite smooth and dense, having no Haversian canals, and they are covered with a layer of cartilage. Strong ligaments pass from one bone to the other to hold each in its place (*A*, Fig. 102). Some of these consist simply of bands, connecting the joint on its different sides, while others form continuous sheaths around the joint.

The interior of the joint, except where the bone surfaces rub upon each other, is covered with a serous lining, called the *synovial membrane* (*B*, Fig. 102). This secretes a thick, viscid liquid, the *synovial fluid*, which prevents friction. The synovial membrane does not cover the ends of the bones, but passes around the joint and connects with the bones at their edges so as to form a closed sac in which the fluid is retained.

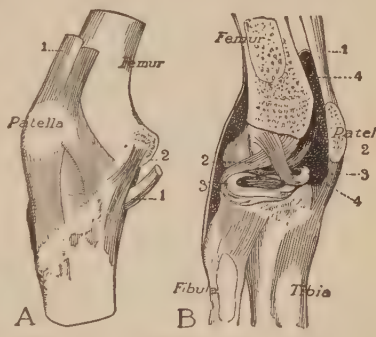

FIG. 102. — **Outside and inside view of knee joint.** 1. Tendons. 2. Ligaments. 3. Cartilage. 4. Space containing synovial fluid. This space is lined, except upon the articular surfaces, by the synovial membrane.

Kinds of Movable Joints. — The different kinds of movable joints are the ball and socket joint, the hinge joint, the pivot joint, the condyloid joint, and the gliding joint. These are constructed and admit of motion, as follows:

1. In the *ball and socket* joint the ball-shaped end of one bone fits into a cup-shaped cavity in another bone, called the socket. The best examples of such joints are

found at the hips and shoulders. The ball and socket joint admits of motion in all directions.

2. In the *hinge* joint the bones are grooved and fit together after the manner of a hinge. Hinge joints are found at the elbows and knees and also in the fingers. The hinge joint gives motion in but two directions — forward and backward.

3. A *pivot* joint is formed by the fitting of a pivot-like projection of one bone into a ring-like receptacle of a second bone, so that one, or the other, is free to turn. A good example of the pivot joint is found at the elbow, where the radius turns upon the humerus. Another example is the articulation of the atlas with the axis vertebra as already noted. The pivot joint admits of motion around an axis.

4. The *condyloid* joint is formed by the fitting of the ovoid (egg-shaped) end of one bone into an elliptical cavity of a second bone. Examples of condyloid joints are found at the knuckles and where the wrist bones articulate with the radius and ulna. They move easily in two directions, like hinge joints, and slightly in other directions.

5. *Gliding* joints are formed by the articulation of plain (almost flat) surfaces. Examples of gliding joints are found in the articulations between the bones of the wrist and those of the ankle. They are the simplest of the movable joints and are formed by one bone gliding, or slipping, upon the surface of another.

Summary. — The skeleton, or framework of the body, is a structure which is movable as a whole and in most of its parts. It preserves the form of the body, protects important organs, and supplies the mechanical devices, or machines, upon which the muscles act in the production of motion. The skeleton is adapted to its purposes

through the number and properties of the bones, and through the cartilage and connective tissue associated with the bones. The places where the different bones connect one with another are known as joints, and most of these admit of motion.

Exercises. — 1. State the main purpose of the skeleton. What is the necessity for so many bones in its construction?

2. How may the per cent of animal and of mineral matter in a bone be determined?

3. What properties are given the bones by the animal matter? What by the mineral matter?

4. Locate the bone cells. What is their special function?

5. State the plan by which nourishment is supplied to the bone cells in different parts of the bone.

6. Give the uses of the periosteum.

7. State the purpose of the Haversian canals. Of the canaliculi.

8. Give functions of the spinal column.

9. Name the different materials used in the construction of a joint and the purpose served by each.

10. Name four mechanical devices, or machines, found in the skeleton and state the purpose served by each.

11. Name one or more of the body machines not located in the skeleton.

PRACTICAL WORK

To obtain clear ideas of the form and functions of the bones, a careful examination of a prepared and mounted skeleton is necessary. Many of the bones, however, may be located and their general form made out from the living body. Bones of the lower animals may also be studied to advantage.

Experiments to show the Composition of Bone. — 1. Examine a slender bone, like that in a chicken's leg. Note that it resists bending and is difficult to break. Note also that it is elastic — that, when slightly bent, it will spring back.

2. Soak such a bone over night in a mixture of one part hydrochloric acid and four parts water. Then ascertain by bending, stretching, and

twisting what properties the bone has lost. The acid has dissolved out the mineral matter.

3. Burn a small piece of bone in a clear gas flame, or on a bed of coals, until it ceases to blaze and turns a white color. Can the bone now be bent or twisted? What properties has it lost and what retained? What substance has been removed from the bone by burning?

Observation on the Gross Structure of Bone. — 1. Procure a long, dry bone. (One that has lain out in the field until it has bleached will answer the purpose excellently.) Test its hardness, strength, and stiffness. Saw it in two a third of the distance from one end, and saw the shorter piece in two lengthwise. Compare the structure at different places. Find rough elevations on the outside for the attachment of muscles, and small openings into the bone for the entrance of blood vessels and nerves. Make drawings to represent the sections.

2. Procure a fresh bone from the butcher shop. Note the difference between it and the dry bone. Examine the materials surrounding the sides and covering the ends of the bone. Saw through the enlarged portion at the end and examine the red marrow. Saw through the middle of the bone and observe the yellow marrow.

To show the Minute Structure of the Bone. — Prepare a section of bone for microscopic study as follows: With a jeweler's saw cut as thin a slice as possible. Place this upon a good-sized whetstone, not having too much grit, and keeping it wet rub it under the finger, or a piece of leather, until it is thin enough to let the light shine through. The section may then be washed and examined with the microscope. If the specimen is to be preserved for future study, it may be mounted in the usual way, but with *hard* balsam. Prepare and study both transverse and longitudinal sections, making drawings. The sections should be prepared from bones that are thoroughly dry but which have not begun to decay.

To show the Structure of a Joint. — Procure from a butcher the joint of some small animal (hog or sheep). Cut it open and locate the cartilage, synovial membrane, and ligaments. Observe the shape and surface of the rubbing parts and the strength of the ligaments.

CHAPTER XX

HYGIENE OF THE SKELETON

An interesting fact about our living is that we are daily exposed to a molding process that can slowly change our shape. This operates through the positions we are constantly assuming and affects our bones, cartilage, and the skeleton as a whole.

How the Skeleton is Molded. — The power that our positions have of molding us into different shapes is dependent upon two conditions. First, the materials forming the skeleton are to some extent *plastic*. They give slightly when pressure is applied to them.[1] Second, the skeleton is constantly under pressure from having to support the body weight. Since we cannot change the properties of our bones and cartilage and cannot escape the pressure that comes from our weight, we cannot keep the molding process from going on. We can so control it, however, that it becomes a beneficial instead of a harmful process.

When the Molding is in the Right Direction and when Otherwise. — The skillful molder can put a piece of soft clay into any desired shape by pressure applied at its different surfaces. The problem is quite similar in the case of the skeleton. To have the molding of the skeleton go on as it should, *we must keep ourselves in the right shape*. This

[1] Proof of this is found in the disfigurement of the skull of the flat-head Indian by pressure from a board, and in the deforming of the feet of Chinese women by binding them. The dentist, on the other hand, turns the plastic nature of bone to good account in widening the jaws and in bringing irregular teeth into line.

so distributes our weight that the resulting pressure tends to keep us in, or change us to, the shape that we should be. On the other hand, getting into and keeping bad shapes, causes the pressure from our weight to mold us in the opposite direction. The right and the wrong methods of body molding are both illustrated in Figure 103.

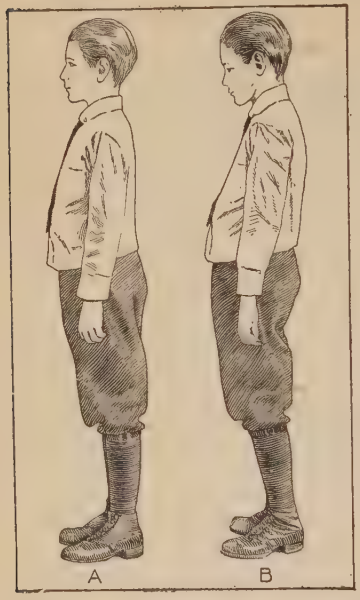

FIG. 103. — **Correct** (A) **and incorrect** (B) **molding.** (Courtesy American Posture League.)

If we are to control the molding of our bodies by keeping correct positions, we must know what these are and how to keep them. This means special knowledge and special effort.

When our Postures are Correct. — In order to decide what positions are correct, we must investigate the spinal column. This, as already explained (p. 228), forms the central axis of the body and is to the body as the foundation is to the house. If it is kept in the right shape, our different organs stay where they belong and blood vessels and nerves are not interfered with.[1] The spinal column, moreover, is put into different shapes by the various positions which we assume. Certain positions keep it in ex-

[1] An illustration of the bad effect of getting the spine out of shape are the pains that occur in the shoulders, back, hips, and legs, as a result of keeping in some bad position. These are called *postural pains*. They are relieved by taking and keeping the correct positions.

actly the right shape, while others get it much out of shape. In general, we may say that correct positions are those that keep the spinal column in the right shape.

What the Correct Shape of the Spinal Column is. — This is indicated in Figure 104. Viewed from the back, the spinal column presents a straight line; there are no curves either to the right or the left. Viewed from the side, it has three curves and a straight portion. It has two backward curves — one at the shoulders and one at the hips — and a forward curve between these two. The neck is practically straight. If the spinal column of a person does not conform to this shape, it usually means, though not always,[1] that the molding process has not been properly managed.

FIG. 104. — **Diagram of the Ideal Shape of the Spine.** *A.* viewed from behind; *B.* viewed from the side.

How the Right Shape of the Spine is Maintained. — The spinal column is kept in the right shape by avoiding diseases and accidents that injure it and by standing and sitting in proper positions. To avoid sideward curves of the spine we must keep the shoulders the same height and the hips on a level. To maintain the right curve between the shoulders and the hips, we must keep the chest up, or forward, the hips well back, and the abdomen drawn in. And to keep the neck straight, we must keep the chin down and the head up. These suggestions are all included in the rules for correct standing and sitting, as follows:

[1] The spinal column and the body as a whole may get into bad shape from disease and accident as well as from incorrect posture. The serious deformity, called "hunchback," is the result of tuberculosis of the spine.

1. Stand " tall " with the chest up, the chin down, the hips back, the abdomen in, and the weight upon both feet.

2. Sit " tall " with the chest up, the chin down, the hips well back in the chair, and both feet on the floor. In bending, bend at the hips.

Although these rules should be constantly practiced, it is not necessary for one to keep rigidly in the same position all the time. He should change positions as the muscles get tired. By bending at the hips when sitting, one can find several positions in which the spine is still in the right shape.

Time and the Process of Molding. — If one should keep himself in good shape for a few minutes each day, but should be in some bad shape for the rest of the time, the general trend of his molding would be in the wrong direction. To really improve upon the bodily shape or to preserve the normal shape when one has it, the correct position must be kept *most of the time*. This brings us to the main problem in this study — that of properly controlling our positions in standing and sitting.

Our Postures when we are not Thinking about Them. — Our positions are subject to two kinds of control — a *conscious* control that comes through the mind and a *natural* control which works independently of the mind. Under the natural control our positions are determined mostly by comfort, convenience, and habit. This means that any position which we take when we are not thinking about ourselves will be the one which is most comfortable under the circumstances, which is most convenient for our work, or one which we have formed the habit of taking. Since our positions are most of the time under natural control, it is highly important that we get back to the conditions that influence these postural guides.

Causes for the Natural Control's not Working Properly. — When a person fails to take the correct position except when he is thinking about it, *something is wrong with his natural control.* Some condition is present which causes the correct position to be uncomfortable or inconvenient, such as follow.

1. *A misshaped spinal column.* If the spinal column is already out of shape, it gives a feeling of discomfort to force it into the correct shape and to hold it so. Successful natural control requires a spinal column that is of the right shape.

Fig. 105.— **Showing bad effect of high heels on posture.**

2. *Weak back muscles.* The skeleton is dependent upon the muscles for keeping it in shape. It cannot of itself stand or sit alone. If the muscles, especially those of the back, are weak or lack in tone (p. 257), one is easily fatigued and naturally takes a position in which one part is braced to some extent by another. Such a position is usually incorrect.

3. *Defective vision.* If one does not see well, he is forced to bend over in order to get near his work or his books.

4. *High-heeled shoes.* These make one stand, as it were, on a slope, and this, in turn, makes the correct standing position uncomfortable and tiresome. To avoid this, the body naturally sways forward at the hips and backward at the shoulders, while the head droops forward more or less (Fig. 105).

5. *Unhygienic chairs and other body supports.* If a chair is so constructed that sitting in the correct position is tiresome or uncomfortable, one naturally takes a bad position for the sake of the rest or the comfort.

6. *Depressing states of mind.* Grief, discouragement, fear, melancholia, and similar states have a damaging effect on posture, due to their effect, through the nerves, upon the muscles (p. 258).

7. *Bad postural habits.* One can easily form habits of standing and sitting in wrong positions when these are no more comfortable or convenient than those that are right.

In the correction of these conditions we have several well-defined problems which we may now consider.

To Improve the Shape of the Spine. — Serious bends in the spinal column that have resulted from disease or accident will require the aid of specialists in this line of medical work. The slight defects, however, that have resulted from an improperly directed molding process, can be corrected by the person himself. The most important rule to observe for this purpose is: Keep the entire body in its correct shape *as much of the time as possible.* The effect of this, if practiced sufficiently, is gradually to mold the spine back into the right shape. In following this plan, there are certain parts that require special attention. These are:

1. *The head.* Keep the head high and the chin slightly depressed. This is to avoid an undue forward inclination of the neck.

2. *The chest.* Keep the chest up in sitting, standing, and walking. This corrects the tendency to flat chest and round shoulders. The shoulders themselves require little attention.

3. *The hips.* The hips must be kept far enough back to keep the entire body in a straight vertical line and to avoid a general forward swaying in this region.

4. *The abdomen.* To avoid too much of a forward curve in the back (swayback) the muscles in the walls of the abdomen should be contracted.

In remolding the spinal column according to this plan,

we must avoid exaggerations that would cause stiffness or actual defects in the opposite direction. What we want is the natural shape with good poise, ease, and comfort.

To Develop and Strengthen the Supporting Muscles. — This is a matter of exercise of the right kinds in sufficient amounts. In addition to general exercise that comes through such games as volley ball and tennis and such forms of work as wood chopping and bed making, the "setting up" exercises now so generally practiced (p. 272) are most excellent for the development of the muscles that support the body in the upright position.

To Keep the Vision Keen. — If there is difficulty in seeing, the eyes must be corrected with glasses. Unless this is done, correct postures that mold and keep the body in the right shape are practically impossible.

To Keep the Feet Healthy and in the Right Shape. — The feet form a necessary base over which the body is balanced. The way we balance ourselves over this double and movable base has much to do with our positions in standing and walking. Large feet are better than small ones in that they make the balancing easier. Balancing in correct positions is also easier when the feet are comfortable and when we have broad low heels to our shoes, instead of the high heels that prop the feet up at the back. For the sake of our posture and for other reasons, our shoes should be properly made and fitted in all respects — giving sufficient room for the toes (not too narrow), having an almost straight inner edge from the shank to the toe, and having broad heels not more than an inch high (Fig. 106).

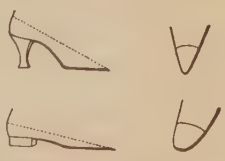

FIG. 106. — **Heels and toes** of unhygienic and of hygienic footwear.

Hygienic Chairs and Other Body Supports. — These are recognized by the fact that one can sit in them comfortably when he is in a correct position. A chair that is hygienic lets the feet rest comfortably on the floor, has a slightly backward slope to the hollowed out seat, and supports the lower part of the back. In other words, it conforms in its construction to the correct shape of the body in a sitting position. But more important than the chairs in the home are the seats and desks in the schoolroom. Hence, the improvements made in these in recent years deserve special commendation (Fig. 107).

FIG. 107. — **Adjustable seat and desk** used in schools of Boston, Mass.

To Correct our Habits of Standing and Sitting. — Habits that will make us take the right positions in standing and sitting in spite of misshaped spines, weak back muscles, defective eyes, high-heeled shoes, or uncomfortable chairs are not possible. Habits that cause us to take the better of two positions of equal comfort and convenience, however, are possible and are easily established. Habits of this character are the following:

The habit of sitting up straight when reading and writing.

The habit, when sitting, of bending at the hips, instead of the back, when it is necessary to bend at all.

The habit of keeping the hips well back in the chair, instead of sliding forward on the seat.

The habit, in standing, of letting the weight rest equally upon the two feet.

The habit of sitting and standing with the chest up.

The habit of equalizing the weight on the two sides of the body in carrying books and other articles.

Some habit of adjustment that will keep our work from getting us into some bad shape. This habit needs further explanation.

To Keep our Work from Injuring our Shape. — There are many kinds of work that invite stooping positions either for comfort or convenience. Unless one in such work fights against the tendency, he will be molded into some bad shape. He must find some adjustment that will preserve the natural shape of his body and cause, at the same time, the work to be carried on to good advantage. The adjustment which men tailors have found most helpful is that of sitting on a table while at work, with the legs crossed. Some bookkeepers have been able to keep in good shape by sitting so near the desk at which they worked that they could not bend forward, and others have found it best to do all their work in the standing position.

Pupils at school have a problem of this kind which will vary with the task and the construction of the school seats and desks. One must find the best position and then form the habit of taking it. The mistake must not be made of depending upon comfort as a proper guide to the best position.

To Keep the Good Shape we Already Have. — Most people start out in life with a correctly shaped body. Small children almost without exception stand, walk, and sit correctly. As they get older, and especially as they attend school, they get molded out of shape. To keep in good shape we must give much attention to posture. We must take and hold the correct position whenever we think of it, and we must remove, as far as possible, the conditions that cause us to take bad positions unconsciously. It is only by this means that we can preserve our natural shape throughout life.

To Work for Postural Improvements. — Most of us, however, have a harder task than that of preserving a shape which is already perfect. We have bodies that are more or less out of shape, and it is necessary that we improve them. This requires earnest and persistent effort whose aim is that of remolding the skeleton. Success will be ours, however, if we work with vigor and determination and do not stop before the task is finished.

Rewards. — Successful effort in looking after the bodily shape insures better health, improved personal appearance, and greater efficiency in whatever one does. Besides these rewards, there is yet another for young people — a reward that depends upon the fact that "as the twig is bent, the tree's inclined." The young person who habitually sits and stands correctly will *grow into correct shape*, thereby making it much easier to preserve the natural shape in later life.

Summary. — All through life we are exposed to a molding process that can change our shape. Correct positions mold and keep us in the right shape, while incorrect positions do the reverse. Since we cannot avoid this molding process, we must control it to our advantage. We do this by conscious effort in taking and keeping correct positions and by supplying in our bodies and in our methods of living conditions that cause us to take correct positions unconsciously. Correct bodily shape is one of the easiest of our health foundations to control.

Exercises. — 1. How do we account for the fact that our positions are able to mold us from one shape to another?

2. What kinds of postures mold us into the correct shape? What kinds into incorrect shape?

3. Define correct postures from the standpoint of the spinal column.

4. Describe positions in standing and sitting that keep the spine in its right shape.

5. By what two methods are our different positions controlled?

6. By what different things are we guided in the natural control of our positions? What may be wrong when we are unable to sit and stand correctly without thinking about it?

7. Discuss the general plan of putting the slightly misshaped backbone into correct shape.

8. Why are strong back muscles necessary to good posture? How do we get and keep them?

9. How do high-heeled shoes cause one to stand incorrectly? Describe a shoe that is hygienic.

10. Describe a chair that aids one in sitting correctly.

11. Why do young people need to give more attention to posture than do adults?

12. Why must one persist in his efforts to maintain correct positions? What are the rewards?

13. Name the health foundations that have been studied so far.

14. How does correct bodily shape compare in importance with our other foundations of health? Give reasons for your answer.

CHAPTER XXI

THE MUSCULAR SYSTEM

As already stated, the skeleton, the nervous system, and the muscular system are concerned in the production of motion. The skeleton and the nervous system, however, serve other purposes in the body, while the muscular system is devoted mainly to the production of motion.[1] For this reason it is looked upon as the special *motor* system. The muscular tissue is the most abundant of all the tissues, forming about 41 per cent of the weight of the body.

Properties of Muscles. — The ability of muscular tissue to produce motion depends primarily upon two properties — the property of irritability and the property of contractility. *Irritability* is that property of a substance which enables it to respond to a stimulus, or to act when acted upon. *Contractility* is the property which enables the muscle when stimulated to draw up, thereby becoming shorter and thicker (a condition called contraction), and when the stimulation ceases, to return to its former condition (of relaxation). The property of contractility enables the muscles to produce motion. Irritability is a condition necessary to their control in the body.

Kinds of Muscular Tissue. — Three kinds of muscular tissue are found in the body. These are known as the *striated*, or striped, muscular tissue; the *non-striated*, or plain, muscular tissue; and the *muscular tissue of the heart*. These are made up of different kinds of muscle cells and act in different ways to cause motion. The

[1] The muscles serve minor purposes in supporting the bony framework, protecting delicate organs, and supplying heat.

striated muscular tissue far exceeds the others in amount and forms all those muscles that can be felt from the surface of the body. The non-striated muscle is found in the walls of the food canal, blood vessels, air passages, and other tubes of the body; while the muscular tissue of the heart is confined entirely to that organ.

Striated Muscle Cells. — The cells of the striated muscles are slender, thread-like structures, having an average length of $1\frac{1}{2}$ inches (35 millimeters) and a diameter of about $\frac{1}{400}$ of an inch (60 μ). Because of their great length they are called fibers, or fiber cells. They are marked by a number of dark, transverse bands, or stripes, called striations,[1] which seem to divide them into a number of sections, or disks (Fig. 108). A thin sac-like covering, called the *sarcolemma*, surrounds the entire cell and just beneath this are a number of nuclei.[2]

FIG. 108. — **A striated muscle cell** highly magnified, showing striations and nuclei. Attached to the cell is the termination of a nerve fiber.

Within the sarcolemma are minute fibrils and a semiliquid substance, called the *sarcoplasm*. At each end the cell tapers to a point from which the sarcolemma appears to continue as a fine thread, and this, by attaching itself to the inclosing sheath, holds the cell in place. Most of the muscle cells receive, at some portion of their length, the termination of a nerve fiber. This penetrates the sarcolemma and spreads out upon a kind of disk, having several nuclei, known as the *end plate*.

[1] On account of the striations of these cells the muscles which they form are called striated muscles.

[2] The striated muscle cells, having many nuclei, are said to be multi-nucleated.

The "Muscle-organ." — We must distinguish between the term "muscle" as applied to the muscular tissue and the term as applied to a working group of muscular tissue, which is an organ. In the muscle, or muscle-organ, is found a definite grouping of muscle fibers such as will enable a large number of them to act together in the production of the same movement. An examination of one of the striated muscles shows the individual fibers to lie parallel in small bundles, each bundle being surrounded by a thin layer of connective tissue. (See Practical Work.) These small bundles are bound into larger ones by thicker sheaths and these in turn may be bound into bundles of still larger size (Fig. 109). The sheaths surrounding the fiber bundles are connected with one another and also with the outer covering of the muscle, known as

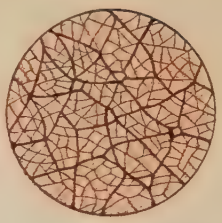

FIG. 109. — **Diagram** of a section of a muscle, showing the perimysium and the bundles of fiber cells.

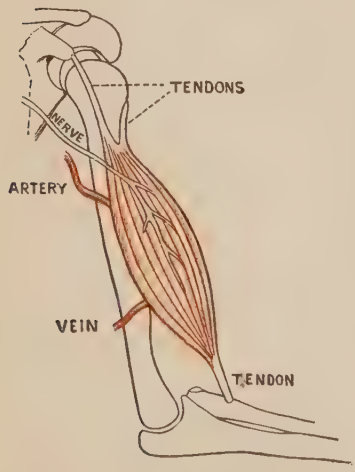

FIG. 110. — **A muscle-organ in position.** The tendons connect at one end with the bones and at the other end with the fiber bundles and perimysium. (See text.)

The Perimysium. — The plan of the muscle-organ is revealed through a study of the perimysium. This is not limited to the surface of the muscle, as the name suggests, but properly includes the sheaths that surround the bundles of fibers. Further-

more, the surface perimysium and that within the muscle are both continuous with the strong, white cords, called *tendons*, that connect the muscles with the bones. By uniting with the bone at one end and blending with the perimysium and fiber bundles at the other, the tendon forms a very secure attachment for the muscle. The perimysium and the tendon are thus the means through which the fiber cells in any muscle-organ are made to *pull together* upon the same part of the body (Fig. 110).

Purpose of Striated Muscles. — The striated muscles, by their attachments to the bones, supply motion to all the mechanical devices, or machines, located in the skeleton. Through them the body is moved from place to place and all the external organs are supplied with such motion as they require. Because of the attachment of the striated muscles to the skeleton, and their action upon it, they are called *skeletal* muscles. As most of them are under the control of the will, they are also called *voluntary* muscles. They are of special value in adapting the body to its surroundings.

Structure of the Non-striated Muscles. — The cells of the non-striated muscles differ from those of the striated muscles in being decidedly spindle-shaped and in having but a single well-defined nucleus (Fig. 111). Furthermore, they have no striations, and their connection with the nerve fibers is less marked. They are also much smaller than the striated cells, being less than one one-hundredth of an inch in length and one three-thousandth of an inch in diameter.

In the formation of the non-striated muscles, the cells are attached to one another by a kind of muscle cement to form thin sheets or slender bundles. These differ from the striated muscles in several particulars. They are of a pale, whitish color, and they have no tendons. Instead of

being attached to the bones, they usually form a distinct layer in the walls of small cavities or of tubes (Fig. 111). Since they are controlled by the part of the nervous system which acts independently of the will, they are said to be *involuntary*. They contract and relax slowly.

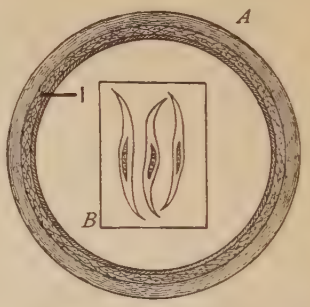

FIG. 111.—**Non-striated muscle cells.** *A*. Cross section of small artery magnified, showing (1) the layer of non-striated cells. *B*. Three non-striated cells highly magnified.

Work of the Non-striated Muscles. — The work of the non-striated muscles, both in purpose and in method, is radically different from that of the striated. They do not change the *position* of parts of the body, as do the striated muscles, but they alter the *size* and *shape* of the parts which they surround. Their purpose, as a rule, is to move, or control the movement of, materials within cavities and tubes, and they do this by means of the *pressure* which they exert. Examples of their action have already been studied in the propulsion of the food through the alimentary canal and in the regulation of the flow of blood through the arteries (pages 174 and 51). While they do not contract so quickly, nor with such great force as the striated muscles, their work is more closely related to the vital processes.

Structure of the Heart Muscle. — The cells of the heart combine the structure and properties of the striated and the non-striated muscle cells, and form an intermediate type between the two. They are cross-striped like the striated cells, and are nearly as wide, but are rather short (Fig. 112). Each cell has a well-defined nucleus, but the sarcolemma is absent. They are placed end to end to form fibers, and

many of the cells have branches by which they are united to the cells in neighboring fibers. In this way they interlace more or less with each other, but are also cemented together. They contract quickly and with great force, but are not under control of the will. Muscular tissue of this variety seems excellently adapted to the work of the heart.

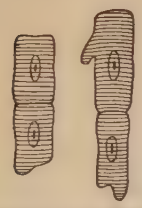

FIG. 112. — **Muscle cells from the heart,** highly magnified (after Schäfer).

The Muscular Stimulus. — The inactive, or resting, condition of a muscle is that of relaxation. It does work through contracting. It becomes active, or contracts, only when it is being acted upon by some force outside of itself, and it relaxes again when this force is withdrawn. Any kind of force which, by acting on muscles, causes them to contract, is called a *muscular stimulus*. Electricity, chemicals of different kinds, and mechanical force may be so applied to the muscles as to cause them to contract. These are *artificial* stimuli. So far as known, muscles are stimulated *naturally* in but one way. This is through the nervous system. The nervous system supplies a stimulus called the *nervous impulse*, which reaches the muscles by the nerves, causing them to contract. By means of nervous impulses, all of the muscles (both voluntary and involuntary) are made to contract as the needs of the body for motion require.

Muscle Tone. — Although relaxation is the resting state of the muscles, they do not during our waking moments completely enter into that state. They remain in a state of "elastic tension" which is midway between contraction and complete relaxation and from which they can easily go into regular contraction. This state is referred to as one of *tone*, or *tonicity*, and is a great aid to quick

action on the part of the muscles. In addition to this, it is necessary wherever a constant pressure or tension has to be kept up, as in the walls of the blood vessels and in the back muscles in holding the erect position. Correct posture, as already explained (p. 245), is much easier when the back muscles are kept in good tone.

Muscle tone appears to be due to the constant discharge of nervous impulses into the muscles, being entirely absent in muscles that are paralyzed. It is improved by good health and sufficient exercise, and is diminished by lack of exercise, fatigue, nerve shocks, depressing mental states, and ill health generally.

Energy Transformation in the Muscle. — The muscle serves as a kind of engine, doing work by transforming potential into kinetic energy. Evidences of this are found in the changes that accompany contraction. Careful study shows that during any period of contraction, oxygen and food materials are consumed, waste products, such as carbon dioxid, are produced, and heat is liberated.

Plans of Using Muscular Force. — Two rather serious difficulties have to be overcome in the using of muscular force in the body. The first of these is due to the fact that the muscles exert their force *only when they contract.* They can pull but not push. Hence, in order to bring about the opposing movements of the body,[1] each muscle must work against some force that produces a result directly opposite to that which the muscle produces. Some of the muscles (those of breathing) work against the elasticity of certain parts of the body; others (those holding body in an upright position), to some extent against gravity; and others

[1] Every movement in the body has its opposing movement. This is necessary both on account of the work to be accomplished and for preserving the natural form of the body.

(the non-striated muscle in arteries), against pressure. But in most cases, *muscles work against muscles.*

The striated, or skeletal, muscles are nearly all arranged after the last-named plan. As a rule a pair of muscles is so placed, with reference to a joint, that one moves the part in one direction, and the other moves it in the opposite direction. From the kinds of motion which the various muscle pairs produce, they are classified as follows:

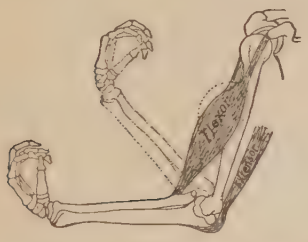

FIG. 113.—The muscle pair that operates the forearm. For names of these muscles, see Fig. 115.

1. *Flexors and Extensors.*—The flexor muscles bend and the extensors straighten joints (Fig. 113).

2. *Adductors and Abductors.*—The adductors draw the limbs into positions parallel with the axis of the body and the abductors draw them away.

3. *Rotators* (two kinds).—The rotators are attached about pivot joints and bring about twisting movements.

4. *Radiating and Sphincter Muscles.*—The radiating muscles open and the sphincter muscles close the natural openings of the body, such as the mouth.

The pupil should locate examples of the different kinds of muscle pairs in his own body.

Exchange of Muscular Force for Motion.—The second difficulty to be overcome in the use of muscular force in the body is due to the fact that the muscles contract through *short* distances, while it is necessary for most of them to move portions of the body through *long* distances. It may be easily shown that the longest muscles of the body do not shorten more than three or four inches during

contraction. To bring about the required movements of the body, which in some instances amount to four or five feet, requires that a large proportion of the muscular force be exchanged for motion. The machines of the skeleton, while providing for motion in definite directions, also provide the means whereby *strong forces*, acting through *short distances*, are made to produce movements of *less force*, through *long distances*. The mechanical device employed for this purpose is known as

The Lever. — The lever may be described as a stiff bar which turns about a fixed point of support, called the *fulcrum*. The force applied to the bar to make it turn is called the *power*, and that which is lifted or moved is termed the *weight*. The weight, the power, and the fulcrum may occupy different positions along the bar and this gives rise to the three kinds of levers, known as levers of the first class, the second class, and the third class (Fig. 114). In levers of the *first class* the fulcrum occupies a position somewhere between the power and the weight. In the *second class* the weight is between the fulcrum and the power. In the *third class* the power is between the fulcrum and the weight.

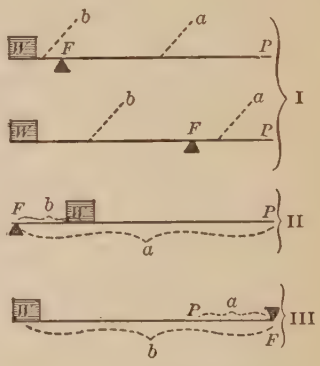

FIG. 114. — **Classes of levers.** I. Two levers of first class showing fulcrums in different positions. II. Lever of second class. III. Lever of third class. *F.* Fulcrum. *P.* Power. *W.* Weight. *a.* Power-arm. *b.* Weight-arm.

Application to the Body. — In the body the bones serve as levers; the turning points, or fulcrums, are found at the joints; the muscles supply the power; and parts of the

body, or things to be lifted, serve as weights. In most of the body levers, the muscles are attached to the bones *near the joints*. This causes the (muscle) power-arm to be *shorter* than the (body) weight-arm,[1] and this, in turn, multiplies the contracting distance of the muscle as many times as the latter is longer than the former.

Loss of Muscular Force. — Using a small spring balance for measuring the power, a light stick for a lever, and a small piece of metal for a weight, and arranging these to represent some lever of the body (as the forearm), it is easily shown that the gain in motion causes a corresponding loss in muscular power. (See Practical Work.) If, for example, the balance is attached two inches from the fulcrum and the weight twelve inches, the pull on the balance is found to be six times greater than the weight that is being lifted. If other positions are tried, it is found that the power exerted in each case is as many times greater than the weight as the weight-arm is times longer than the power-arm.

Applying this principle to the levers of the body, it is seen that the gain in motion is at the expense of muscular force, or, as we say, *muscular force is exchanged for motion.* This exchange is greatly to the advantage of the body; for while the ability to lift heavy weights is important, the ability to move portions of the body rapidly and through long distances is much more to be desired.

Important Muscles. — There are about five hundred separate muscles in the body. These vary in size, shape, and plan of attachment, to suit their special work. Some of those that are prominent enough to be felt at the surface are as follows:

[1] The distance from the fulcrum to the power is called the *power-arm* and the distance from the fulcrum to the weight is called the *weight-arm* (Fig. 114).

Of the head. The *temporal*, in the temple, and the *masseter*, in the cheek. These muscles are attached to the lower jaw and are the chief muscles of mastication.

Of the neck. The *sterno-mastoids*, which pass between the mastoid processes, back of the ears, and the upper end of the sternum. They assist in turning the head and may be felt at the sides of the neck (Fig. 115).

Of the upper arm. The *biceps* on the front side, the *triceps* behind, and the *deltoid* at the upper part of the arm beyond the projection of the shoulder.

Of the forearm. The *flexors* of the fingers, on the front side, and the *extensors* of the fingers, on the back of the forearm (Fig. 115).

Of the hand. The *adductor pollicis*, between the thumb and the palm.

Of the trunk. The *pectoralis major*, between the upper front part of the thorax and the shoulder; the *trapezius*, between the back of the shoulders and the spine; the *rectus abdominis*, passing over the abdomen from above downward; and the *erector spinæ*, found in the small of the back.

Of the hips. The *gluteus maximus*, fastened between the lower back part of the hips and the upper part of the femur.

Of the upper part of the leg. The *rectus femoris*, the large muscle on the front of the leg which connects at the lower end with the kneepan.

Of the lower leg. The *tibialis anticus* on the front side, exterior to the tibia, and the *gastrocnemius*, the large muscle in the calf of the leg. This is the largest muscle of the body, and is connected with the heel bone by the *tendon of Achilles* (Fig. 115).

The use of these muscles is, in most instances, easily determined by observing the results of their contraction.

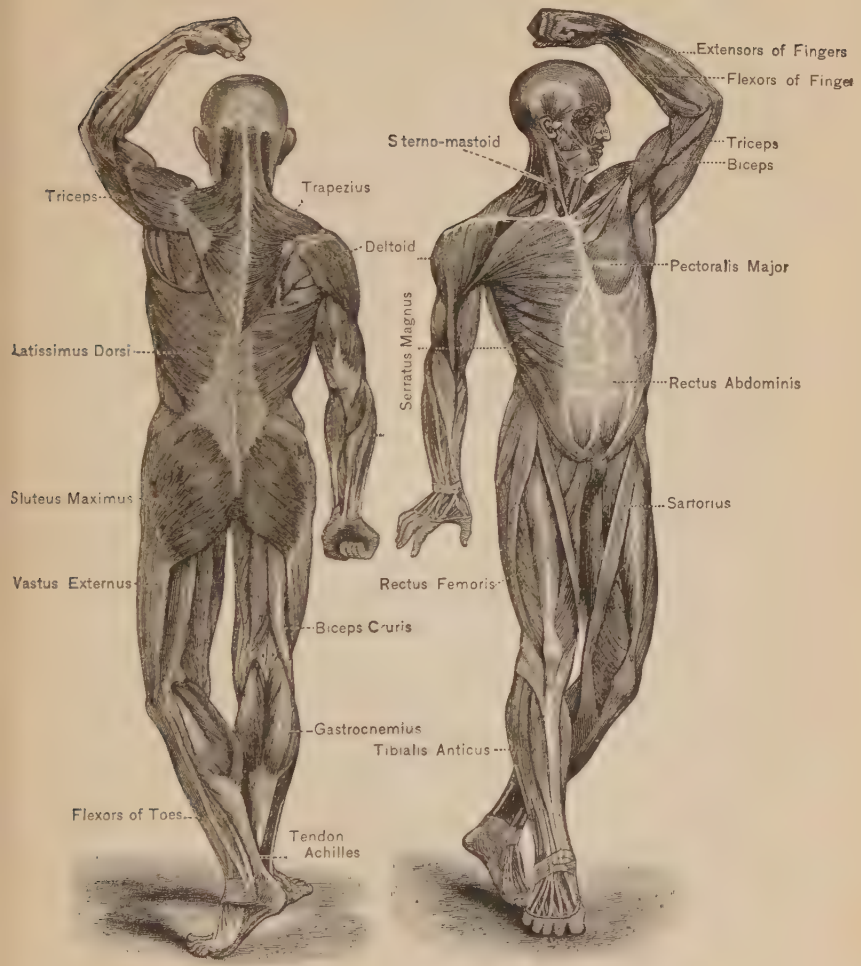

FIG. 115. — Back and front views of important muscles.

Summary. — Motion is provided for in the body mainly through the muscle cells. These are grouped into working parts, called muscles, which in turn are attached to the movable parts of the body. The striated muscles, as a rule, are attached to the mechanical devices found in the skeleton, and bring about the voluntary movements. The non-striated muscles surround the parts on which they act, and produce involuntary movements. Both, however, are under the control of the nervous system. To bring about the opposing movements of the body, the striated muscles are arranged in pairs; and to increase their motion, the bones are used as levers. To enable the muscles to act quickly and to maintain a constant pressure where this is needed, they are kept in a partly contracted state which is called *tone*.

Exercises. — 1. Compare the striated and non-striated muscles with reference to their cells, location, and work.

2. Describe a muscle-organ. How does it enable a group of muscle cells to pull together on the same bone in the body?

3. In what respect is the heart muscle like the striated, and what respect like the non-striated, muscular tissue?

4. Why should most of the muscles attached to the skeleton be voluntary and the muscles of the heart and blood vessels be involuntary?

5. Describe the condition called muscle tone. What purposes does it serve and upon what does it depend?

6. If muscles could push as well as pull, would so many be needed in the body? Why?

7. Why must every movement of the body have its opposing movement? How are these brought about by the muscles?

8. Locate three muscles that act as flexors; three that act as extensors; two that act as adductors; and two that act as abductors. Locate sphincter and radiating muscles.

9. Locate the muscles that bend the fingers. That straighten them. That draw the thumbs toward the index fingers.

10. Describe the plan by which muscles contracting through short distances cause parts of the body to move through long distances.

11. Measure the distance from the center of the palm of the hand to the elbow joint. Find the attachment of the tendon of the biceps muscle to the bone in the forearm and measure its distance to the elbow joint. From these measurements, calculate the distance moved by the hand when the biceps contracts one inch.

PRACTICAL WORK

The reddish muscle found in a piece of beef is a good example of striated muscle. The clear ring surrounding the intestine of a cat (shown by cross section) and the outer portion of the preparation from the cow's stomach, sold at the butcher shop under the name of *tripe*, are good examples of non-striated muscular tissue. The heart of any animal, of course, shows the heart muscle.

To show the Structure of Striated Muscle. — Boil a tough piece of beef, as a cut from the neck, until the connective tissue has thoroughly softened. Then with some pointed instrument, separate the main piece into its fiber bundles and these in turn into their smallest divisions. The smallest divisions obtainable are the muscle cells or fibers.

To show Striated Fibers. — Place a small muscle from the leg of a frog in a fifty-per-cent solution of alcohol and leave it there for half a day or longer. Then cover with water on a glass slide, and with a couple of fine needles tease out the small muscle threads. Protect with a cover glass and examine with a microscope, first with a low and then with a high power. The striations, sarcolemma, and sometimes the nuclei and nerve plates, may be distinguished in such a preparation.

To show Non-striated Cells. — Place a clean section of the small intestine of a cat in a mixture of one part of nitric acid and four parts of water and leave for four or five hours. Thoroughly wash out the acid with water and separate the muscular layer from the mucous membrane. Cover a small portion of the muscle with water on a glass slide and tease out, with needles, until it is as finely divided as possible. Examine with a microscope, first with a low and then with a high power. The cells appear as very fine, spindle-shaped bodies.

To illustrate Muscular Stimulus and Contraction. — Separate the muscles at the back of the thigh of a frog which has just been killed and draw the large sciatic nerve to the surface. Cut this as high up as possible and, with a sharp knife and a small pair of scissors, dissect it

out to the knee. Now cut out entirely the large muscle of the calf of the leg (the gastrocnemius), but leave attached to it the nerve, the lower tendon, and the bones of the knee. Mount on an upright support, as shown in Fig. 116, and fasten the tendon to a lever below by a thread or small wire hook:

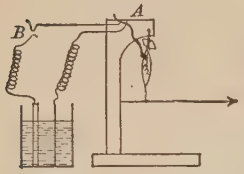

FIG. 116. — **Apparatus** for demonstrating properties of muscles.

1. Lay the nerve over the ends of the wires from a small battery which are attached to the support at *A*, and arrange a second break in the circuit at *B*. At this place the battery circuit is made and broken either by a telegraph key or by simply touching and separating the wires. Note that the muscle gives a single contraction, or twitch, both when the current is made and when it is broken.

2. Remove the current and pinch the end of the nerve, noting the result. With very fine wires, connect the battery directly to the ends of the muscle. Stimulate by making and breaking the current as before. In this experiment the muscle cells are stimulated by the direct action of the current and not by the current acting on the nerve.

3. With the wires attached to either the muscle or the nerve, make and break the current in rapid succession. This causes the muscle to enter into a second contraction before it has relaxed from the first, and if the shocks follow in rapid succession, to continue in the contracted state. This condition, which represents the method of contraction of the muscles in the body, is called *tetanus*.

NOTE. — In these experiments a twitching of the muscle is frequently observed when no stimulus is being applied. This is due to the drying out of the nerve and is prevented by keeping it wet with a physiological salt solution. (See footnote, page 41.)

To show the Action of Levers. — With a light but stiff wooden bar, a spring balance, and a wedge-shaped fulcrum, show:

1. The position of the weight, the fulcrum, and the power in the different classes of levers, and also the weight-arm and the power-arm in each case.

2. The direction moved by the power and the weight respectively in the use of the different classes of levers.

3. That when the power-arm and weight-arm are equal, the power equals the weight and moves through the same distance.

4. That when the power-arm is longer than the weight-arm, the weight is greater, but moves through a shorter distance than the power.

5. That when the weight-arm is longer than the power-arm, the power is greater and moves through a shorter distance than the weight.

To show the Loss of Power in the Use of the Body Levers. — Construct a frame similar to, but larger than, that shown in Fig. 116, (about 12 inches high), and hang a small spring balance (250 grams capacity) at the place where the muscle is attached. Fasten the end of a lever to the upright piece, at a point on a level with the end of the balance hook. (The nail or screw used for this purpose must pass loosely through the lever, and serve as a pivot upon which it can turn.) The lever should consist of a light piece of wood, and should have a length at least three times as great as the distance from the hook to the turning point. Connect the balance hook with the lever by a thread or string. and then hang upon it a small body of known weight. Note the amount of force exerted at the balance in order to support the weight at different places on the lever. At what point is the force just equal to the weight? Where is it twice as great? Where three times? Show that the force required to support the weight increases proportionally as the weight-arm and as the distance through which the weight may be moved by the lever. Apply to the action of the biceps muscle in lifting weights on the forearm.

A Study of the Action of the Biceps Muscle. — Place the fingers upon the tendon of the biceps where it connects with the radius of the forearm. With the forearm resting upon the table, note that the tendon is somewhat tight (indicating muscle tone), but that it tightens more (from muscular contraction) as the arm is raised. Now press the body of the muscle, and sweep the forearm through two or three complete movements, noting the changes in the length and thickness of the muscle. Lay the forearm again on the table, back of hand down, and place a heavy weight (a flatiron or a hammer) upon the hand. Note the effort required to raise the weight, and then shift it along the arm. Observe that the nearer it approaches the elbow the lighter it seems. Account for the difference in the effort required to raise the weight at different places. Does the effort vary as the distance from the tendon?

CHAPTER XXII

RIGHT LIVING AND THE MUSCLES

One effect of modern life has been to deprive vast numbers of people of needed exercise. This, through its effect upon muscle tone, has been a serious detriment to health.

Muscle Tone and Good Health. — Muscle tone, or tonicity, is a condition necessary to the proper working of the muscles (p. 258). To understand how its loss can injure the health, we have only to see how conditions on which our cells are dependent are in turn dependent upon muscular action.

Muscles in the walls of the arteries and veins keep the capacity of the blood vessels equal to the volume of the blood and control the amount flowing to different organs (p. 51). A complete loss of tone of these muscles would stop the flow of blood completely.

Muscles in the walls of the stomach and intestines mix the food with the digestive juices and move the waste through the food canal.

Muscles in the diaphragm and attached to the ribs move air into and from the lungs (pp. 91 and 92).

Muscles in the walls of the abdomen support the stomach and intestines, and, through their contractions, improve the circulation in these organs.

Muscles in the back and in the neck keep the body in an upright position and are the greatest of all our aids to correct posture.

All of the active muscles produce heat, and heat is necessary to life.

In general we may say that most of our health foundations (p. 22) require good muscle tone for their upkeep.

Muscle Tone and Exercise. — Other conditions present (p. 248), muscles sufficiently exercised are kept in good tone. Those that are insufficiently exercised lose in tone and become soft, weak, and flabby. This is a fact that every one should take into account in his living. Exercise must be supplied in sufficient amount and variety to keep up a good degree of tone *in all of our muscles.*

Why Getting Sufficient Exercise is a Problem. — The getting of sufficient exercise is not, for most people, as simple a matter as might be supposed. In the first place, their mode of living is not such as to cause them to take exercise *naturally.* Nature's plan of having us exercise is that of using the muscles to satisfy bodily needs — the need for food, for clothing, for shelter, etc. Although this plan is well adapted to people who make their living through muscular work, it leaves those who are otherwise situated without a natural incentive to exercise.[1]

In the second place, we are easily misled by Nature's warning against overexercise — the sensation of fatigue. Fatigue plainly says to us, "Rest," and our natural inclination is to obey the command. However, if we always rest when we feel tired, we are sure to omit exercise at times when we need it.

Kinds of Fatigue and their Meaning. — To know when to yield to the feeling of fatigue and when to ignore it, we must know something of the nature of this feeling and the

[1] The question is sometimes asked, "Why do we not have an appetite to cause us to exercise as we have to cause us to take food?" The answer to this question is found in the way in which the human race developed. Primitive man got all the exercise he needed in satisfying his bodily needs and in escaping from his enemies. Since he had no need for an exercise appetite, it did not develop.

causes that induce it. There are at least three kinds of fatigue, as follows:

1. *Positive fatigue.* This kind results from long-continued or strenuous exercise and is due to the using up of energy-producing materials in the nerve and muscle cells. It is a state of real exhaustion.

2. *Negative fatigue.* This results from only slight exertion when one is not used to exercising. It is not due to exhaustion, but to the accumulation of waste in the muscle and nerve cells and in the blood.

3. *Chronic fatigue,* or "tired feeling." This may be present without exercise, as on rising in the morning, but rapidly increases with exertion. It is due to an excess of waste throughout the body.

If one has positive fatigue he should, of course, rest, and to restore his muscle and nerve cells to their former condition, he may also need food and sleep. If one has negative fatigue, he should rest for but a short time and then continue his exercising. In this way he will get his body in a condition such that he will not have this kind of fatigue. If he has chronic fatigue he may need, in addition to considerable exercise, some kind of medical treatment that will enable him to throw off his waste. Thus, it is seen that only one kind of fatigue, the positive, requires rest for its relief. The others require more exercise.

Mind and the Problem of Exercise. — By what means shall one whose vocation does not supply a sufficient amount and variety of exercise provide for this daily need? The answer to this question is found in the relation which exists between the mind and the muscles. As brought out in the preceding chapter, most of the muscles are controlled and directed by the mind. It is also a fact that the voluntary muscles, in contracting, bring about conditions

that improve the tone of the involuntary muscles. This shows very plainly that one of the duties of the mind is that of looking after the muscles. It is, in a sense, the muscles' keeper.

Planning for Exercise. — Mind has many duties to perform, and it also has its limitations. For these reasons, it cannot be depended upon regularly for supplying the stimulus to exercise — for forcing us to exercise when we need it and to take it in the right amounts. But we can and should depend upon the mind *to supply conditions that will cause us to exercise naturally*, that is, without having to think about it. Some of the ways by which this may be done are the following:

1. By planning situations that force us to exercise in order to supply bodily needs, as in the case of a student's rooming in one part of town and boarding in another.

2. By undertaking some kind of muscular work that requires daily attention, such as gardening, delivering papers, or some kind of housework.

3. By joining a gymnasium class, a hiking squad, or a club that requires physical exercise as a part of its regular work.

4. By the formation of habits of taking certain exercises at certain times each day.

5. By getting interested in and learning to play outdoor games.

Of course, there are forms of exercise for which the mind must be directly responsible — exercises for special purposes and bearing directly upon the health. Every indoor worker should know about some of these.

Special Exercises. — Some of the exercises for keeping in good tone important groups of muscles are the following:

1. *Exercises for the back muscles.* (*a*) The exercise of

chest lifting. Keeping the chin down and the middle of the neck pushed back, push the chest up and forward by pressing in the spine just below the shoulders. As the chest is pushed up a deep breath may be taken and as the normal position is resumed, this is expelled. Repeat many times during the day.

(*b*) A four-part exercise. Standing with the feet side by side and the hands at the sides, step forward with the left foot, swinging both hands forward and upward to a position over the head and back far enough to give a decided bend to the back. Hold this position for two seconds and then bend forward until the fingers touch, or almost touch, the floor, keeping the knees stiff. Hold for one second and then return to the second position and again hold for two seconds. Then return the hands to the sides and the left foot to the original position. Repeat, stepping forward with the right foot and then again with the left, counting 1, 2, 3, 4 for the different positions.

2. *Exercises for "toning up" the muscles in the abdominal walls and in the walls of the stomach and intestines.* While all kinds of trunk bending and twisting exercises are good for this purpose and these can be taken in any position, the best ones are taken while lying flat on the back. The beginner would do well to start with the "head-lifting exercise," which is conveniently taken after retiring at night, as follows: Lying on the back with pillow pushed to one side, gently lift the head and shoulders a slight distance from the mattress and as gently let them drop back, keeping neck almost straight. Repeat until thoroughly fatigued. Another exercise of the same nature, but more strenuous, is taken by lying on the back and drawing up the knees, and another by lying on the back and lifting oneself to the sitting position.

3. *Exercises for "toning up" the muscles in the walls of the blood vessels.* These muscles are called actively into play by all conditions that induce changes in the blood supply to different organs. While the usual forms of physical exercise necessitate such changes and indirectly exercise the muscular coat, the exposure of the body for short intervals to moderate degrees of cold does the same thing in a much more effective manner. Hence, we must look upon the cold bath, taken with due precautions (p. 285), and the brisk walk on a frosty morning, as supplying necessary exercise for the muscles in the walls of the blood vessels.

4. *Exercises for "toning up" the eye muscles.* The eyes work better and are much less apt to get strained when the muscles that turn the eyeballs in different directions and the muscles used in focusing are kept in good tone. The following simple exercises will do this: First, look up, then down, and then up again many times. Second, look to the right, then to the left, and then to the right again, many times. Third, rotate, or turn, the eyeballs first one way and then the other, many times. Fourth, look at a pencil held about a foot from the eyes, then at something far distant, and then at the pencil, many times. And fifth, close the eyes tightly and then open them as wide as possible, and then close again, many times. Eye exercises should be taken several times a day by all those who use their eyes very much on close work.

Exercise as a Health Agent in Itself. — In addition to its effect in keeping up muscle tone, physical exercise is considered one of the most important of our health agencies. Properly taken, exercise

Strengthens the heart and quickens the flow of the blood,

Increases the appetite and improves the digestion,

Makes our oxidations and other chemical changes take place more rapidly,

Causes waste from the cells to be thrown off more rapidly and completely,

Develops the lungs and makes one breathe more deeply,

Improves the bodily shape,

Makes the skin healthier and more active, and

Causes one to sleep more soundly and to be more refreshed by his sleeping.

Rules for Healthful Exercise. — In order that exercise produce the best results from the standpoint of health, however, a number of conditions must be observed: 1. It should not be excessive or carried to the point of exhaustion. Severe physical exercise is destructive to both muscular and nervous tissues. 2. It should, if possible, be of an interesting nature and taken in the open air. 3. It should be counter-active, that is, calling into play those parts of the body that have not been used during the regular work.[1] 4. It should be directed toward the weak rather than toward the strong parts of the body. 5. When one is really tired (has positive fatigue), he must take exercise with moderation or omit it for the time being.

Massage. — In lieu of exercise taken in the regular way, muscle tone may be kept up by a systematic rubbing, pressing, and kneading of the skin and the muscles, by one trained in the art. This process, known as *massage*, may be gentle or vigorous and is subject to a variety of modifications. Massage is applied when one is unable to take exercise, on account of disease or accident, and also in the treatment of certain bodily disorders. A weak ankle, wrist, or other part of the body, or even

[1] *Walking* is considered one of the very best forms of counter-active exercise for the brain worker (p. 337).

a bruise, may be greatly benefited by massage. The flow of blood and lymph is stimulated, causing new materials to be passed to the affected parts and waste materials to be removed. Massage, however, should never be applied to a boil or other infected sore. The effect in this case would be to spread the infection and increase the trouble.

Summary. — In our methods of living we must supply exercise in sufficient amounts and variety to keep all of our muscles in good tone. This, for many, will require considerable planning. On the one hand, we must provide conditions that cause us to exercise *naturally* and, on the other, we must take special exercises for special purposes as our needs require. Good muscles is the sixth of our health foundations so far studied.

Exercises. — 1. In what ways is good health dependent upon good muscle tone?

2. What is the proof that good muscle tone is dependent upon exercise?

3. Why is the getting of sufficient exercise a problem?

4. Name and define the different kinds of fatigue. Which one indicates a need for rest and which a need for more exercise?

5. Why do we speak of the mind as " the muscles' keeper "?

6. Mention several ways by which we can cause ourselves to take exercise *naturally* or without having to think about it.

7. Discuss some special exercises for special purposes. How do we get ourselves to take them?

8. Name three ways in which the " head-lifting exercise " benefits the health.

9. How can short exposures to cold exercise the muscles in the walls of the blood vessels?

10. In what other ways does exercise benefit the health besides keeping up the tone of the muscles?

11. What general rules should be observed in exercising to improve the health?

CHAPTER XXIII

THE SKIN

PROTECTIVE coverings are found at all the exposed surfaces of the body. These vary considerably at different places, each being adapted to the conditions under which it serves. The most important ones are the *skin*, which covers the entire external surface of the body; the *mucous membrane*, which lines all the cavities that communicate by openings with the external surface; and the *serous membrane*, which, including the synovial membranes, lines all the closed cavities of the body. In addition to the protection which it affords, the skin is one of the means by which the body is brought into proper relations with its surroundings. It is because of this function that we take up the study of the skin at this time.

The Skin is one of the most complex structures of the body, and serves several distinct purposes. It is estimated to have an area of from 14 to 16 square feet, and to have a thickness which varies from less than one eighth to more than one fourth of an inch. It is thickest on the palms of the hands and the soles of the feet, the places where it is most subject to wear. It is made up of two distinct layers — an outer layer called the *epidermis*, or cuticle, and an inner layer called the *dermis*, or cutis vera (Fig. 117).

The Dermis. — This is the thicker and heavier of the two layers, and is made up chiefly of connective tissue. The network of tough fibers which this tissue supplies,

forms the essential body of the dermis and gives to it its power of resistance. It is on account of the connective tissue that the skins of animals can be converted into leather by tanning. A variety of structures, including

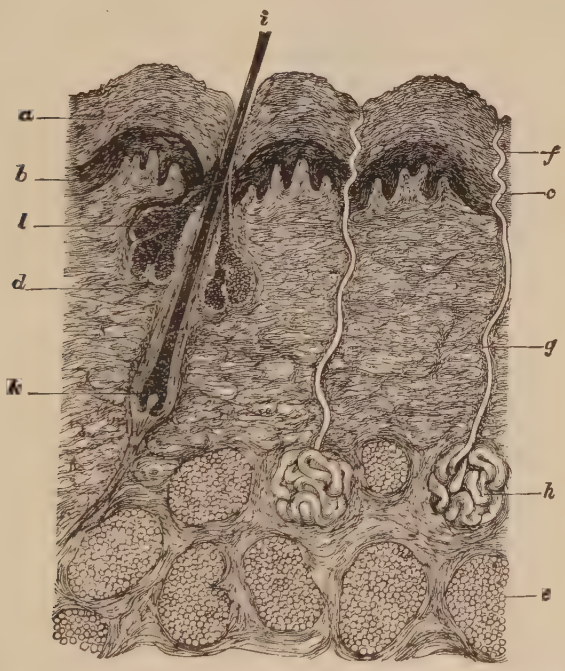

FIG. 117. — **Section of skin** magnified. *a, b.* Epidermis. *b.* Pigment layer. *c.* Papillæ. *d.* Dermis. *e.* Fatty tissue. *f, g, h.* Sweat gland and duct. *i, k.* Hair and follicle. *l.* Oil gland.

blood and lymph vessels, oil and perspiratory glands, hair follicles, and nerves, are found embedded in the connective tissue (Fig. 118). These aid in different ways in the work of the skin.

On the outer surface of the dermis are numerous eleva-

tions, called *papillæ*. These average about one one-hundredth of an inch in height, and one two hundred and fiftieth of an inch in diameter. They are most numerous on the palms of the hands, the soles of the feet, and the under surfaces of the fingers and toes. At these places they are larger than in other parts of the body, and are closely grouped, forming the parallel curved ridges which cover the surfaces. Each papilla contains a loop of capillaries and a small nerve, and many of them are crowned with touch corpuscles (page 351).

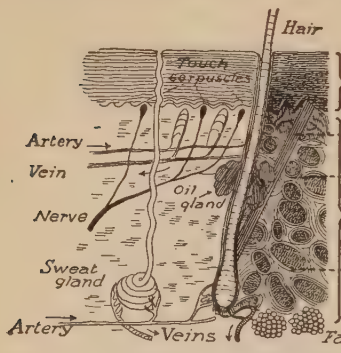

FIG. 118.— **Diagram** of section of skin showing its different structures.

The Epidermis is much thinner than the dermis. It is made up of several layers of cells which are flat and scale-like at the surface, but are rounded in form where the epidermis joins the dermis. The epidermis has the appearance of being *moulded onto* the dermis, filling up the depressions between the papillæ and having corresponding irregularities (Fig. 117). No blood vessels are found in the epidermis, its nourishment being derived from the lymph which reaches it from the dermis. Only the part next to the dermis is made up of *living* cells. These are active, however, in the formation of new cells, which take the place of those that are worn off at the surface. Some of the cells belonging to the inner layer of epidermis contain *pigment granules*, which give the skin its color (Fig.

117). The epidermis contains no nerves and is therefore non-sensitive. The hair and the nails are important modifications of the epidermis.

A Hair is a slender cylinder, formed by the union of epidermal cells, which grows from a kind of pit in the dermis, called the *hair follicle*. The oval and somewhat enlarged part of the hair within the follicle is called the *root*, or *bulb*, and the uniform cylinder beyond the follicle is called the *shaft*. Connected with the sides of the follicles are the *oil*, or *sebaceous*, *glands* (Figs. 117 and 118). These secrete an oily liquid which keeps the hair and cuticle soft and pliable. Attached to the inner ends of the follicles are small, involuntary muscles whose contractions cause the roughened condition of the skin that occurs on exposure to cold.

A Nail is a tough and rather horny plate of epidermal tissue which grows from a depression in the dermis, called the *matrix*. The back part of the nail is known as the *root*, the middle convex portion as the *body*, and the front margin as the *free edge* (Fig. 119). Material for the growth of the nail is derived from the matrix, which is lined with active epidermal cells and is richly supplied with blood vessels. Cells added to the root cause the nail to grow in length (forward) and cells added to the under surface cause it to grow in thickness. The cuticle adheres to the nail around its entire circumference so that the covering over the dermis is complete.

FIG. 119. — **Section of end of finger** showing nail in position.

Functions of the Skin. — The chief function of the skin is that of protection. It is able to protect the body on account of the tough connective tissue in the dermis, the non-sensitive cells of the epidermis, and also by the touch

corpuscles and their connecting nerve fibers. This protection is of at least three kinds, as follows:

1. *From mechanical injuries* such as might result from contact with hard, rough, or sharp objects. The main quality needed for resisting mechanical injuries is *toughness*, and this is supplied both by the epidermis and by the connective tissue of the dermis.

2. *From chemical injuries* caused by contact with various chemical agents, as acids, alkalies, and the oxygen of the air. The epidermis, being of such a nature as to resist to a considerable extent the action of chemical agents, affords protection from these substances.[1]

3. *From disease germs* which are everywhere present. The epidermis is the main protective agent against attacks of germs, but should the epidermis be broken, they meet with further resistance from the fluids of the dermis and the white corpuscles of the blood.

4. *From an excessive evaporation of liquid from the surface of the body.* In the performance of this function, the skin is an important means of keeping the tissues soft and the blood and lymph from becoming too concentrated.

Other Functions of the Skin. — Through the perspiratory glands the skin is an *organ of excretion.* While the secretion from a single gland is small, the waste that leaves the body through all of the perspiratory glands is considerable[2] (page 215). By means of the nerves terminating in the touch corpuscles, the skin serves as the *organ of touch*, or feeling (Chapter XXVII). To a slight extent also the skin

[1] The epidermis does not afford complete protection against chemicals, many of them being able to destroy it quickly. The rule of washing the skin immediately after contact with strong chemical agents should always be followed.

[2] "Rough calculations have placed the number of sweat glands on the entire body at about 2,000,000." Rettger, *Studies in Advanced Physiology.*

may absorb liquid substances, these being taken up by the blood and lymph vessels, and perform a respiratory function, throwing off carbon dioxid. But the most important function of the skin, in addition to protection, is that of serving as

An Organ of Adaptation. — Forming, as it does, the boundary between the body and its physical environment, the skin is perhaps the most important agent through which the body is adapted to its immediate surroundings. Evidence of this is found in the great variety of influences which are able to affect the body through their action upon the nerves in the skin, and in the changes which the epidermis undergoes on exposure. The latter function is especially marked in the lower animals, the coverings of epidermal tissue (hair, scales, feathers, etc.) adapting each species to the physical conditions under which it lives. In man the most striking example of adaptation through the skin is seen in the variations in the quantity of blood circulating through it, corresponding to the changes in the temperature outside of the body. These variations are of great importance, having to do with the

Maintenance of the Normal Temperature. — It is necessary to the continuance of life that the temperature of the body be kept at a nearly uniform degree, called the *normal temperature*, which is about 98.6° F. The maintenance of the normal temperature depends mainly upon four conditions: the chemical changes at the cells, the circulation of the blood, the nervous system, and *the skin*. The chemical changes produce the heat, the blood in its circulation distributes the heat over the body, and the nervous system controls the heat-producing and distributing processes (page 330). The skin is the chief means by which the body

gets rid of an excess of heat and, by so doing, avoids overheating.[1]

How the Skin cools the Body. — The skin is a means of ridding the body of an excess of heat in at least two ways:

1. *By the conduction and radiation of heat from its surface* as from a stove. This goes on all the time, but varies with the amount of heat brought to the surface by the blood.

2. *By the evaporation of the perspiration.* It is a well-established and easily demonstrated principle that liquids in evaporating use up heat. (See Practical Work.) It is also a matter of everyday experience that the perspiration has a cooling effect upon the body and that its flow increases with the amount of heat to be gotten rid of. The quantity of perspiration secreted, and of heat disposed of through its evaporation, also varies with the amount of blood circulating through the skin.

Temperature Regulation by the Skin. — Variations in the quantity of blood circulating through the skin enable this organ to throw off just the right amount of heat for keeping the body at the normal temperature. If it is necessary for the body to rid itself of an excess of heat, the quantity of blood circulating in the skin is increased. This brings the blood near the surface, where more heat can be radiated and where it may cause an increase in the perspiration. On the other hand, if the body is in danger of losing too much heat, the circulation diminishes in the skin and increases in the internal organs. This stops the rapid loss of heat from the surface. The skin in this work

[1] Heat also leaves the body by the lungs, partly by the respired air and partly through the evaporation of moisture from the lung surfaces. Respiration in some animals, as the dog, is the chief means of cooling the body.

is of course made to coöperate with other parts of the body. That it is not the only organ concerned in regulating the escape of heat is seen in the results that follow sensations either of chilliness or of heat at the surface.

Effects of Heat and Cold Sensations. — Sensations, or feelings, of heat and cold are made possible through the nerves which connect the brain with the *temperature corpuscles*, found in the skin (page 352). As the warm blood recedes from the skin, a sensation of cold is felt, but when the blood returns, there is again the feeling of warmth. The sensation of cold prompts one to seek a warmer place, or to put on more clothing; while the sensation of heat, if it be oppressive, leads to activities of an opposite kind. Prompted in this way by the sensations from the skin, one naturally supplies the external conditions, such as clothing and heat, that affect the body temperature.

Alcohol and the Regulation of Temperature. — Alcohol, through its effect upon the nervous system, interferes seriously with the regulation of the body temperature. By dilating the capillaries, it increases the circulation in the skin and leads to an undue loss of heat. At the same time the excess of blood in the skin causes a *feeling of warmth* which has led to the erroneous belief that alcohol is a heat producer. If taken on a cold day, it deceives one about his true condition and leads to a wasting of heat when it should be carefully economized. Not only is alcohol of no value in maintaining the body temperature, but if taken during severe exposure to cold, it becomes a menace to life itself. Arctic explorers and others exposed to severe cold have found that they withstand cold far better when no alcohol at all is used.[1]

[1] "The story is told of some woodsmen who were overtaken by a severe snowstorm and had to spend the night away from camp; they had a bottle of whisky,

HYGIENE OF THE SKIN

Much of the hygiene of the skin is included in the problems of keeping it warm and clean. It is kept warm by clothing; bathing is the method of keeping it clean.

Clothing should be warm and loose-fitting. Woolen fabrics are to be preferred in winter to cotton because, being poorer conductors of heat, they afford better protection from the cold. But wool fails to absorb the perspiration rapidly from the skin and to pass it to the outside where it is evaporated. This, together with its tendency to irritate, makes woolen clothing somewhat objectionable for wearing next to the skin. This objection, however, is obviated by woolen underwear which is lined by a thin weaving of cotton.

Bathing. — The solid material from the perspiration, which is left on the skin, together with the oil from the oil glands and the dirt from the outside, tends to close up the pores and develop offensive odors. Keeping the skin clean is, for these reasons, necessary from both a health and a social standpoint. While one should always keep clean, the frequency of the bath will depend upon the season, the occupation of the individual, and the nature and amount of the perspiration. As to the kind of bath to be taken and the precautions to be observed, no specific rules can be laid down. These must be determined by

and, chilled to the bone, some imbibed freely while others refused to drink. Those who drank soon felt comfortable and went to sleep in their improvised shelter; those who did not drink felt very uncomfortable throughout the night and could get no sleep, but in the morning they were alive and able to struggle back to camp, while their companions who had used alcohol were frozen to death. . . . This, if true, was of course an extreme case: but it accords with the universal experience of arctic travelers and of lumbermen and hunters in the northern woods, that the use of alcohol during exposure to cold, although contributing greatly to one's comfort for the time being, is generally followed by undesirable or dangerous results." — HOUGH AND SEDGWICK: *The Elements of Hygiene and Sanitation.*

the facilities at hand and by the health and natural vigor of the bather. Severe chilling of the body should be avoided, especially by those in delicate health. If a hot bath is taken, one should dash cold water over the body on finishing. One should then quickly dry and rub the body with a coarse towel. The dash of cold water closes the pores of the skin and lessens the liability of taking cold.

The Tonic Bath. — The cold bath has been found to have a beneficial effect upon the general health beyond its effect upon the skin. When taken with care as to the length of time and the degree of cold, decided tonic effects are observed on the circulation and on the nervous system. The rapid changes of temperature vigorously exercise the non-striated muscles of the blood vessels and the nerves controlling them. The irritability of the nervous system in general is also lessened. For this reason the cold bath is one of the best means of keeping both mind and body in good condition during the warm months. Sponging off the body with cold or tepid water before retiring is also an excellent aid in securing sound sleep during the hot summer nights.

Danger from the cold bath arises through the shock to the nervous system and the loss of heat from the body. It is avoided by using water whose temperature is not too low and by limiting the time spent in the bath. A brisk rubbing with a coarse towel should always follow the cold bath. People past middle age are, as a rule, not benefited by the cold bath; and those in delicate health, especially if inclined toward rheumatism, are likely to be affected injuriously by it.

Care of the Complexion. — A good complexion is a natural accompaniment of good health and depends primarily

upon two conditions — a clear skin and an active circulation of the blood through it. Clearness of the skin depends largely upon the elimination of waste material from the body, and where the solid wastes are not effectively removed through the natural channels (the liver, kidneys, and bowels), blotches, sallowness of the skin, and skin eruptions are likely to result. In seeking to clear the complexion, attention must be given to all those agencies that favor the elimination of waste, and especially should there be a free and thorough evacuation of the bowels each day. The general health should also be looked after, attention being given to exercise, fresh air, proper food,[1] sufficient sleep, etc.

Bathing is the chief means employed for increasing the circulation in the skin, although exercise which is sufficiently vigorous to cause one to perspire freely is a valuable aid. A daily bath of warm or hot water, finished off with a dash of cold, followed by a thorough rubbing of the entire surface, and this by a kneading of the skin with the thumbs and fingers, will in most cases bring about the desired results. A little olive oil, thoroughly worked into the skin during the kneading process, is beneficial where one lacks flesh or where the skin is dry and thin. The olive oil is also beneficial where the baths are exhausting or render one susceptible to cold. In rubbing and kneading, the skin should not be bruised or irritated.

The much advertised "complexion beautifiers" which are applied directly to the face frequently have the effect of clogging the pores and of causing eruptions of the skin.

[1] Foods that are difficult to digest, or which cause disturbances of the digestive organs (a coated tongue being one indication), have a bad effect upon the skin. It is in this way that the use of tea and coffee by some people induces a sallow or "muddy" condition of the complexion.

On the other hand, certain authorities state that the cold cream preparations may be of advantage in giving the skin a desired softness, and that when judiciously used (the face being cleansed after each application) they do no harm. Face powders prepared from rice are considered the least injurious.

Treatment of Skin Wounds. — Skin wounds which may not be serious in themselves frequently become so through getting infected with germs. To prevent this, the wound should be thoroughly cleaned, using pure, warm water if necessary, and then painted with tincture of iodin. After this it should be protected from dirt and the clothing until thoroughly healed. If, in spite of these precautions, it becomes infected, a physician should be consulted, though an experienced person might treat it successfully with an antiseptic ointment obtained from the druggist.[1] Neglected skin infections often result seriously from germs spreading through the blood to other parts (p. 37).

A wound resulting from the bite of an animal (cat or dog), even though slight, should receive more serious attention, and as soon as possible after the occurrence. Such wounds should be cauterized, and for this purpose pure carbolic acid (undiluted with water) may be used. A wooden toothpick is dipped into the acid and this is worked about in the wound. The acid is then washed out with clean, warm water. A deep wound from a rusty nail or

[1] A most valuable antiseptic ointment is prepared by the druggist from the following formula:

Lanolin,	25 grams
Ichthyol,	6 grams
Yellow vaseline,	20 grams

This is applied as a thin layer on the surface, except in the case of boils or abscesses. In treating these a heavy layer is spread over the affected part and then covered with absorbent cotton or a thin piece of clean cotton cloth.

a thorn should be treated in the same manner and should be kept open, not being allowed to heal at the surface first. If one has reason to believe he has been bitten by a mad dog, the wound should be cauterized as above, and a physician should be summoned at once. Deep wounds from explosives, or other causes, should also receive the attention of the physician. Many cases of lockjaw result every year from wounds inflicted by the toy pistols, firecrackers, etc., used in our Fourth of July celebrations. These are due to the embedding in the skin or flesh of small solid particles on which are lockjaw germs. Wounds of this nature should, of course, receive the attention of the physician.

Care of the Nails. — Relief from a blood blister under the nail is secured by boring a small hole through the nail with the sharp point of a sterilized penknife. This simple bit of surgery not only relieves the pain, but is frequently the only means of saving the nail. Ingrown toe nails are relieved by scraping a broad strip in the middle of the nail until very thin. This relieves the pressure, preventing the sides of the nail from being forced into the toe. While the finger nails should be trimmed in a curve, corresponding to the end of the finger, it is recommended that the toe nails be cut straight across (Fig. 120), as this method diminishes the pressure from the shoe and keeps the nails from ingrowing. Shoes that pinch the toes should, of course, not be worn (page 247).

FIG. 120. — **Proper method of trimming nails of toes.**

Care of the Hair. — Occasional washing of the hair is beneficial, but too much wetting causes decay of the hair roots, which leads to its falling out. The worst enemy of the hair is dandruff. A method of removing dandruff which is highly recommended is that of rubbing olive oil

into the scalp and later of removing this with a cleansing shampoo. The olive oil is placed on the scalp with a medicine dropper and thoroughly rubbed in with the fingers. After three or four hours the hair is washed with soap and water (any good toilet soap will do) and rinsed with pure water. The hair is then dried, the surplus water being removed with a coarse towel. Where the dandruff is very troublesome, this treatment may be given once or twice a week; but in mild cases once a month is sufficient. Massage of the scalp, by increasing the circulation at the hair roots, is beneficial, but irritation by a fine-tooth comb, a stiff hair brush, or by other means should be avoided. Frequent brushing and combing, however, are necessary both for the good appearance of the hair and for spreading the oil secreted by the glands at the hair roots.

Summary. — The skin forms the external covering of the body and also serves additional purposes. It is a most important agency in adapting the body to its physical surroundings, as shown by the part which it plays in the regulation of the body temperature. The skin should be kept clean and active, and skin wounds, even though small, should be guarded against infection.

Exercises. — 1. Name an example of each of the protective coverings of the body.

2. Compare the dermis and the epidermis with reference to thickness, composition, and function.

3. To what is the color of the skin due? How is the color of the skin affected by the sunlight?

4. What modifications of the epidermis are found on our bodies? What are found on the body of a chicken?

5. What different kinds of protection are provided by the skin?

6. How does the perspiration cool the body?

7. What change occurs in the circulation in the skin when the body is becoming too cold? When becoming too warm? What is the purpose of these changes?

8. How does alcohol cause one to *feel* warm when he may be losing too much of his heat?

9. What precaution should be observed by one in poor health, in taking a bath?

10. How may the cold bath be a means of improving the general health?

PRACTICAL WORK

Observations on the Skin and its Appendages. — Examine the palm of the hand with a lens. Note the small ridges which correspond to the rows of papillæ beneath the cuticle. In these find small pits, which are the openings of the sweat glands.

2. Examine the epidermis on the back of the hand and palm. At which place is it thickest and most resisting? Is it of uniform thickness over the palm? Try picking it with a pin at the thickest place, noting if pain is felt. Inference?

3. Examine a finger nail. Is the free edge or the root the thickest? Trim closely the thumb nail and the nail of the middle finger of one hand and try to pick up a pin, or other minute object, from a smooth, hard surface. The result indicates what use of the nails? Suggest other uses.

4. Examine with a microscope under a low power, hairs from a variety of animals, as the horse, dog, cat, etc., noting peculiarities of form and surface.

To illustrate Cooling Effects of Evaporation. — 1. Wet the back of the hand and move it through the air to hasten evaporation. Observe that, as the hand dries, a sensation of cold is felt. Repeat the experiment, using ether, alcohol, or gasolene instead of the water, noting the differences in results. These liquids evaporate faster than water.

2. Wet the bulb of a thermometer with alcohol or water. Move it through the air to hasten evaporation. Note and account for the fall of the mercury.

CHAPTER XXIV

STRUCTURE OF THE NERVOUS SYSTEM

Coördination and Adjustment. — If we consider for a moment the movements of the body, we cannot fail to note the coöperation of organs, one with another. In the simple act of whittling a stick one hand holds the stick and the other the knife, while the movements of each hand are such as to aid in the whittling process. Examples of co-operation are also found in the taking of food, in walking, and in the performance of different kinds of work. Not only is coöperation found among the external organs, but our study of the vital processes has shown that the principle of coöperation is carried out by the internal organs as well. The fact that all the activities of the body are directed toward a common purpose makes the coöperation of its parts a necessity. The term "coördination" is employed to express this coöperation, or working together, of the different parts of the body.

A further study of the movements of the body shows that many of them have particular reference to things outside of it. In going about one naturally avoids obstructions, and if anything is in the way he walks around or steps over it. Somewhat as a delicate instrument (the microscope for example) is altered or adjusted, in order to adapt it to its work, the parts of the body, and the body as a whole, have to be *adjusted* to their surroundings. This is seen in the attitude assumed in sitting and in standing, in the position of the hands for different kinds

of work, in the variations of the circulation of the blood in the skin, and in the movements for protecting the body.[1]

Work of the Nervous System. — How are the different activities of the body controlled and coördinated? How is the body adjusted to its surroundings? The answer is found in the study of the nervous system. Briefly speaking, the nervous system controls, coördinates, and adjusts the different parts of the body by fulfilling two conditions:

1. It provides a complete system of connections whereby all parts are brought into communication with a central division (brain and spinal cord) and this in turn with all the body surfaces.

2. It supplies a means of controlling action (the so-called impulse) which it passes along the nervous connections from one part of the body to another.

The present chapter deals with the first of these conditions; the chapter following, with the second.

The Nerve Skeleton. — If all the other tissues are removed, leaving only the nervous tissue, a complete skeleton outline of the body still remains. This nerve skeleton, as it has been called, has the general form of the framework of bones, but differs from it greatly in the fineness of its structures and the extent to which it represents every portion of the body. An examination of a nerve skeleton, or a diagram of one (Fig. 121), shows the main structures of the nervous system and their connection with the different parts of the body.

Corresponding to the skull and the spinal column is a central nervous axis, made up of two parts, the *brain* and the *spinal cord*. From this central axis white, cord-like bodies emerge and pass to different parts of the body.

[1] In a larger sense adjustment includes all those activities by means of which the body is brought into proper relations with its environment, including the changes which the body makes in its surroundings to *adapt them* to its purposes.

These are called *nerve trunks*, and the smaller branches into which they divide are called *nerves*. The nerves also undergo division until they terminate as fine thread-like structures in all parts of the body. The distribution of nerve terminations, however, is not uniform, as might be supposed, but the skin and important organs like the heart, stomach, and muscles are the more abundantly supplied. On many of the nerves are small rounded masses, called *ganglia*, and from many of these small nerves also emerge. At certain places the nerves and ganglia are so numerous as to form a kind of network, known as a *plexus*.

It is through these structures — brain and spinal cord, nerve trunks and nerves, ganglia and nerve terminations — that connections are established between all parts of the body, but more especially between the surface of the body and the organs within.

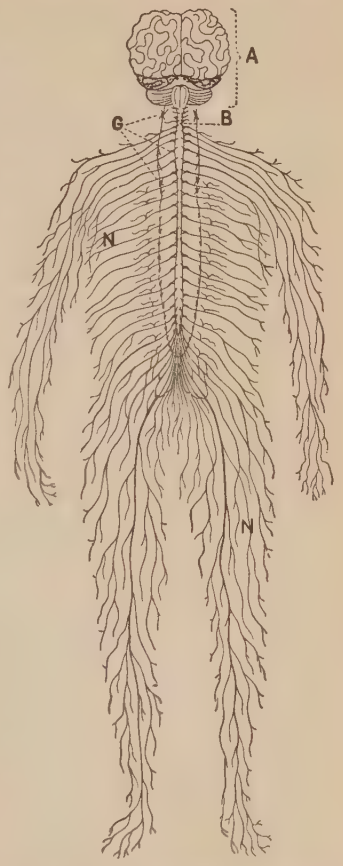

FIG. 121. — **Diagram of nerve skeleton.** The illustration shows the extent and general arrangement of the nervous tissue. *A*. Brain. *B*. Spinal cord. *N*. Nerve trunks and nerves. *G*. Ganglia.

The Neurons, or Nerve Cells. — While a hasty examination of the nerve skeleton is sufficient to show the connection

of the nervous system with all parts of the body, no amount of study of its gross structures reveals the nature of its connections or suggests its method of operation. Insight into the real nature of the nervous system is obtained only through a study of its minute structural elements. These, instead of being called cells, as in the case of the other tissues, are called *neurons*.[1]

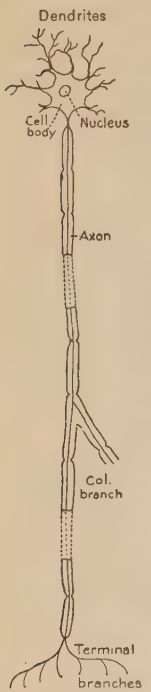

FIG. 122. — **Diagram of an efferent neuron** (greatly enlarged except as to length). The central thread in the axon is the axis cylinder.

The neurons are in all respects cells. They differ widely, however, from all the other cells of the body and are, in some respects, the most remarkable of all cells. They are characterized by minute extensions which, in some instances, reach to great distances. The neurons also present marked differences among themselves, especially in the number and length of their extensions. We shall confine our study to two main types which are named from their general mode of work (p. 307), *efferent*, or motor, neurons and *afferent*, or sensory, neurons.[2]

Efferent, or Motor, Neurons. — Neurons belonging to this class consist of three distinct parts, known as the cell-body, the dendrites, and the axon (Fig. 122).

[1] Almost to the present time, physiologists have described two kinds of nerve elements — *nerve cells* and *nerve fibers*. The nerve cells were supposed to form the ganglia and the nerve fibers to form the nerves. We know now that the so-called nerve cells and nerve fibers are but two parts of the same thing. The term "neuron" is used to denote this single structural element, or *complete nerve cell*.

[2] In general, *afferent* neurons or fibers are those that convey impulses *toward* the central nervous system (brain and cord), while *efferent* neurons or fibers are those that convey impulses *from* the central system.

The *cell-body* has in itself the form of a complete cell and was at one time so described. It consists of a rounded mass of protoplasm, containing a well-defined nucleus. The protoplasm is similar to that of other cells, but is characterized by the presence of many small granules and has a slightly grayish color.

The *dendrites* are short extensions from the cell-body. They branch somewhat as the roots of a tree and form in many instances a complex network of tiny rootlets. Their protoplasm, like that of the cell-body, is more or less granular. The dendrites increase greatly the surface of the cell-body and act as receivers of stimuli (p. 316).

The *axon*, or nerve fiber, is a slender extension from the cell-body which connects with some organ or tissue either near or remote. At its distant end it breaks up into smaller fibers, but it may send out collateral branches before. The axon forms the discharging end of the efferent neuron.

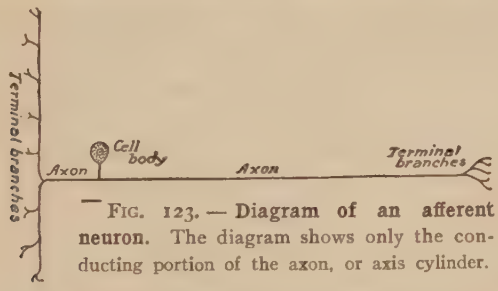

FIG. 123. — **Diagram of an afferent neuron.** The diagram shows only the conducting portion of the axon, or axis cylinder.

Afferent, or Sensory, Neurons. — Neurons of this class have each a well-defined cell-body and two axons, but no parts just like the dendrites of the efferent neurons. The cell-body is smooth, and its axons extend from a side branch in opposite directions (Fig. 123). The outer and less branched end of this neuron is the receiving portion, and the inner and more branched end, the discharging portion.

Structure of the Axon. — The axon, or nerve fiber, has practically the same structure in both classes of neurons, being composed in most cases of three distinct parts. In the center, and running the entire length of the axon, is a thread-like body, called the *axis cylinder* (Fig. 122). The axis cylinder is present in all axons and is the part essential to their work. It may be considered as an extension of the protoplasm from the cell-body. Surrounding the axis cylinder is a thick, whitish-looking layer, known as the *medullary sheath*, and around this is a thin covering, called the *primitive sheath*, or neurilemma. The medullary sheath and the primitive sheath are not, strictly speaking, parts of the nerve cell, but appear to be growths that have formed around it. Certain of the axons have no primitive sheath, and others are without a medullary sheath.[1]

Association, or Intermediate, Neurons. — In addition to the neurons that transmit messages (impulses) inward and toward the brain and the spinal cord and outward from these places, as already described, there are vast numbers of neurons that connect one part of the brain or cord with another. These are called association, or intermediate, neurons. They belong mostly to the type of efferent neurons, but as a rule have axons that are decidedly more branched.

Arrangements of the Neurons. — Nowhere in the body do the neurons exist singly, but they are everywhere connected with each other to form the different structures observed in the nerve skeleton. Two general plans of connection are to be observed, known as the anatomical and the physiological, or, more simply speaking, as the "side-by-side" and "end-to-end" plans. The side-by-

[1] Many of the axons in the brain and spinal cord have no primitive sheath. Axons without the medullary sheath are found in the sympathetic nerves. These are known as non-medullated axons, and they have a gray instead of a white color.

side plan is seen in that disposition of the neurons which enables them to form the nerves and the ganglia, as well as the brain and spinal cord. The end-to-end connections are necessary to the work which the neurons do.

Side-by-side Connections. — On separating the ganglia and nerves into their finest divisions, it is found that the nerves consist of axons, while the ganglia are made up mainly of cell-bodies and dendrites. The axons lie side

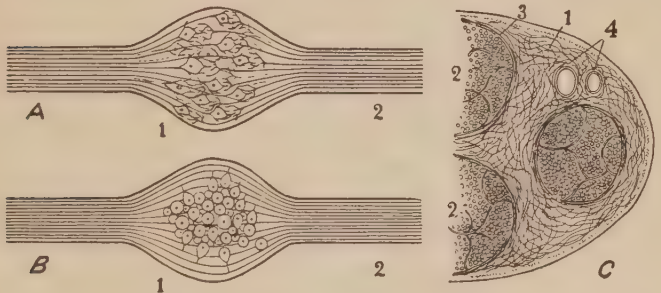

FIG. 124. — **Diagrams illustrating arrangement of neurons.** *A*, *B*. Ganglia and short segments of nerves. 1. Ganglion. 2. Nerve. In the ganglion of *A* are end-to-end connections of different neurons; in the ganglion of *B* are the cell-bodies of di-axonic neurons. *C*. Section of a nerve trunk. 1. Epineurium consisting chiefly of connective tissue. 2. Bundles of nerve fibers. 3. Covering of fiber bundle, or perineurium. 4. Small artery and vein.

by side in the nerve, being surrounded by the same protective coverings, while the cell-bodies form a rounded mass or cluster, which is the ganglion (Fig. 124). But the axons, in order to connect with the cell-bodies, must terminate within the ganglion, so that they too form a part of it. To some extent, also, axons pass through ganglia with which they make no connection. The neurons in the brain and spinal cord also lie side by side, but their arrangement is more complex than that in the nerves and ganglia.

The side-by-side arrangement of the neurons shows clearly the structure of the ganglia and nerves. The nerve is seen to be a bundle of axons, or nerve fibers, held together by connective tissue, while the ganglion is little more than a cluster of cell-bodies. Their connection is necessarily very close, for the same group of neurons will form, with their axons, the nerve, and, with their cell-bodies, the ganglion (Fig. 124).

End-to-end Connections. — These consist of loose end-to-end unions of the fiber branches of certain neurons with

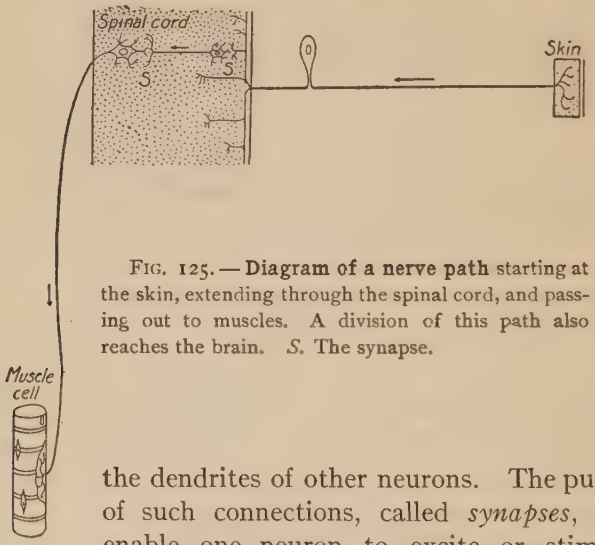

FIG. 125. — **Diagram of a nerve path** starting at the skin, extending through the spinal cord, and passing out to muscles. A division of this path also reaches the brain. *S.* The synapse.

the dendrites of other neurons. The purpose of such connections, called *synapses*, is to enable one neuron to excite or stimulate another. There appears to be no actual uniting of the fiber branches with the dendrites, but they come into relations sufficiently close to establish *conduction pathways*, and these extend throughout the body (Fig. 125). They connect all parts of the body with the brain and spinal cord, and these with the body surfaces and other places from which the end neurons are stimulated.

Nature of the Nervous System. — The nervous system represents the sum total of the neurons in the body. In some respects it may be compared to the modern telephone system. The neurons, like the electric wires, connect different places with a central station (the brain and spinal cord), and through the central station connections are established between the different places in the system. As the separate wires are massed together to form cables, the neurons are massed to form the gross structures of the nervous system. The nervous system, however, is so radically different from anything found outside of the animal body that no comparison can give an adequate idea of it. We now pass to a study of the gross structures observed in the nerve skeleton.

Divisions of the Nervous System. — While all of the nervous structures are very closely blended, forming one complete system for the entire body, this system presents different divisions which may, for convenience, be studied separately. As physiologists have become better acquainted with the human nervous system, different schemes of classification have been proposed. The following outline, based upon the location of the different parts, presents perhaps the simplest view of the entire group of nervous structures:

- Nervous System
  - Central
    - Brain
      - Forebrain — Cerebrum
      - Midbrain
      - Hindbrain
        - Pons
        - Cerebellum
        - Bulb
    - Spinal cord
  - Peripheral
    - Ganglia
      - Dorsal-root ganglia
      - Sympathetic ganglia
    - Nerves
      - Cranial nerves
      - Spinal nerves
      - Sympathetic nerves

The Central Division. — This division of the nervous system lies within the cranial and spinal cavities, and consists of the brain and the spinal cord. The brain occupying the cranial cavity and the spinal cord in the spinal cavity connect with each other through the large opening at the base of the skull to form one continuous structure. The brain and cord are the most complicated portions of the nervous system, and the ones most difficult to understand.

The Brain. — The brain, which is the largest mass of nervous tissue in the body, weighs in the average sized man about 50 ounces, and in the average sized woman about 44 ounces.[1] It may be roughly divided into three parts, which are named from their positions (in lower animals) the forebrain, the midbrain, and the hindbrain (Fig. 126). The forebrain consists almost entirely of a single part, known as

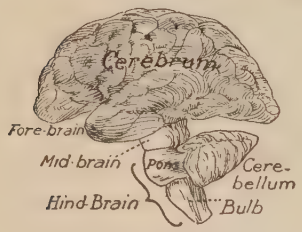

FIG. 126. — Diagram of divisions of brain.

The Cerebrum. — The cerebrum comprises about seven eighths of the entire brain, and occupies all the front, middle, back, and upper portions of the cranial cavity, spreading over and concealing, to a large extent, the parts beneath. The surface layer of the cerebrum is called the *cortex*. This is made up largely of cell-bodies, and has a grayish appearance.[2] The cortex is greatly increased in

[1] The difference in weight between the brain of man and that of woman is due mainly to the fact that man's body is, as a rule, considerably larger than that of woman's.

[2] The nervous tissues present, at different places, two colors — one white, and the other a light gray. Great significance was formerly attached to these colors, because it was supposed that they represented two essentially different kinds of nervous matter. It is now known that the protoplasm in all parts of the neuron

area by the presence everywhere of ridge-like *convolutions*, between which are deep but narrow depressions, called *fissures*. The interior of the cerebrum consists mainly of nerve fibers, or axons, which give it a whitish appearance. These fibers connect with the cell-bodies in the cortex (Fig. 127).

The cerebrum is a double organ, consisting of two similar divisions, called the *cerebral hemispheres*. These are separated by a deep groove, extending from the front to the back of the brain, known as the *median fissure*. The hemispheres, however, are closely connected by a great band of underlying nerve fibers, called the *corpus callosum*.

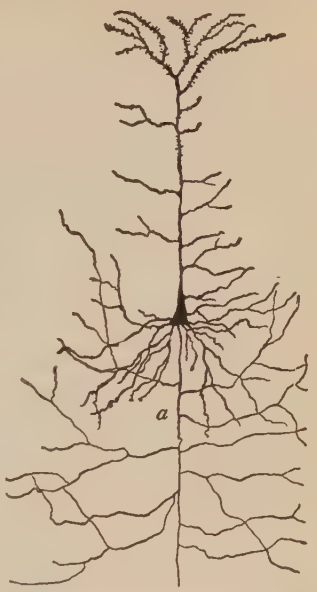

FIG. 127. — **Microscope drawing** of a neuron from cerebral cortex. *a*. Short segment of the axis cylinder with collateral branches.

At the base of the cerebrum three large masses of cell-bodies are to be found. One of these, a double mass, occupies a central position between the hemispheres, and is called the *optic thalami*. The other two occupy front central positions at the base of either hemisphere, and are known as the *corpora striata*, or the striate bodies.

The Midbrain is a short, rounded, and compact body that lies immediately beneath the cerebrum, and connects

proper — cell-body, axis cylinder, and dendrites — has a grayish color, while the coverings of most of the fibers are white. Hence gray matter in any part of the nervous system indicates the presence of cell-bodies, and white matter the presence of nerve fibers.

it with the hindbrain. On account of the great size of the cerebrum, the midbrain is entirely concealed from view when the other parts occupy their normal positions. However, if the cerebrum is pulled away from the hindbrain, it is brought into view somewhat as in Fig. 126.

The midbrain carries upon its back and upper surface four small rounded masses of cell-bodies, called the *corpora quadrigemina*. The upper two of these bodies are connected with the eyes; the lower two appear to have some connection with the organs of hearing. On the front and under surface, the midbrain separates slightly as if to form two pillars, which are called the *crura cerebri*, or cerebral peduncles. These contain the great bundles of nerve fibers that connect the cerebrum with the parts of the nervous system below.

The Hindbrain lies beneath the back portion of the cerebrum, and occupies the enlargement at the base of the skull. It forms about one eighth of the entire brain, and is composed of three parts — the cerebellum, the pons, and the bulb.

The Cerebellum is a flat and somewhat triangular structure with its upper surface fitting into the triangular under surface of the back of the cerebrum. It is divided into three lobes — a central lobe and two lateral lobes — and weighs about two and one half ounces. In its general form and appearance, as well as in the arrangement of its cell-bodies and axons, the cerebellum resembles the cerebrum. It differs from the cerebrum, however, in being more compact, and in having its surface covered with narrow, transverse ridges instead of the irregular and broader convolutions (Fig. 128).

The Pons, or pons Varolii, named from its supposed resemblance to a bridge, is situated in front of the cerebellum, and is readily recognized as a circular expansion which extends forward from that body. It consists largely of

bands of nerve fibers, between which are several small masses of cell-bodies. The fibers connect with different parts of the cerebellum and with parts above.

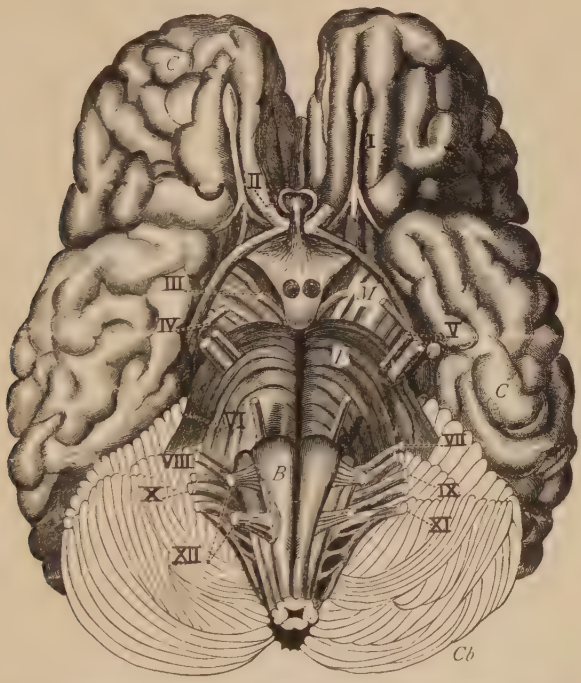

FIG. 128. — **Human brain** viewed from below. *C.* Cerebrum. *Cb.* Cerebellum. *M.* Midbrain. *P.* Pons. *B.* Bulb. I–XII. Cranial nerves.

The Bulb, or medulla oblongata, is, properly speaking, an enlargement of the spinal cord within the cranial cavity. It is somewhat triangular in shape, and lies immediately below the cerebellum. It contains important clusters of cell-bodies, as well as the nerve fibers that pass from the spinal cord to the brain.

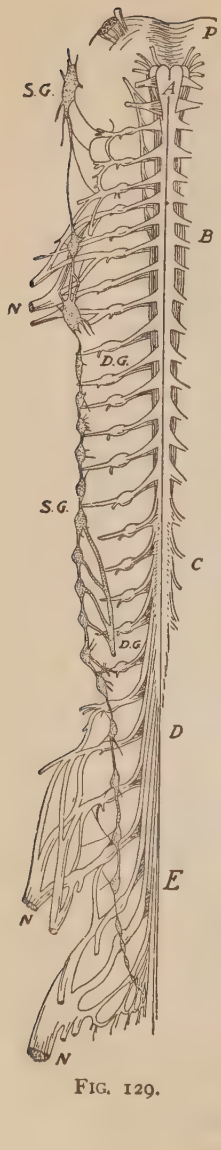

FIG. 129.

The Spinal Cord. — This division of the central nervous system is about seventeen inches in length and two thirds of an inch in diameter. It does not extend the entire length of the spinal cavity, as might be supposed, but terminates at the lower margin of the first lumbar vertebra.[1] It connects at the upper end with the bulb, and terminates at the lower extremity in a number of large nerve roots, which are continuous with the nerves of the hips and legs (Fig. 129). Two deep fissures, one in front and the other at the back, extend the entire length of the cord, and separate it into two similar divisions. These are connected, however, along their entire length by a central band consisting of both gray and white matter.

The arrangement of the neurons of the spinal cord is just the reverse of

[1] In very early life the spinal cord entirely fills the spinal cavity, but as the body develops the cord grows less rapidly than the spinal column, and, as a consequence, separates at the lower end from the inclosing bony column.

FIG. 129. — **Spinal cord,** showing on one side the nerves and ganglia with which it is closely related in function. *A.* Bulb. *B.* Cervical enlargement. *C.* Lumbar enlargement. *D.* Termination of cord. *E.* Nerve roots that occupy the spinal cavity below the cord. *P.* Pons. *D.G.* Dorsal root ganglia. *S.G.* Sympathetic ganglia. *N.* Nerve trunks to upper and lower extremities.

that in the cerebrum — the center being occupied by a double column of cell-bodies, which give it a grayish appearance, while the fibers occupy the outer portion of the cord, giving it a whitish appearance.

The spinal cord is not uniform in thickness, but tapers slightly, though not uniformly, from the upper toward the lower end. At the places where the nerves from the arms and legs enter the cord two enlargements are to be found, the upper being called the *cervical* and the lower the *lumbar enlargement*. These, on account of the difference in length between the cord and the spinal cavity, are above — the lower one considerably above — the places where the limbs which they supply join the trunk (Fig. 129).

Arrangement of the Neurons of the Brain and Cord. — The cell-bodies in the brain and spinal cord are collected into groups, and their fibers extend from these groups to places that may be near or remote. Guided by the white and gray colors of the nervous tissue, and also by the structures revealed by the microscope, physiologists have made out three general schemes in the grouping of cell-bodies, as follows:

1. *That of surface distribution*, the cell-bodies forming a thin but continuous layer over a given surface. This is the plan in the cerebrum and cerebellum, and here are found devices for increasing the surface: the cerebrum having convolutions, the cerebellum transverse ridges.

2. *That of collections of cell-bodies into rounded masses.* Such masses are found in the bulb, the pons, the midbrain, and the base of the cerebrum.

3. *That of arrangement in a continuous column.* This is the plan in the spinal cord. It matters not at what place the spinal cord be cut, a central area of gray matter, resembling in form the capital letter H, is always found.

The fibers connecting with the cell-bodies in the brain and spinal cord are gathered into bundles or tracts, and these pass through different parts somewhat as follows:

1. *In the cerebrum* they extend in three general directions, forming three classes of fibers. The first connect different localities in the same hemisphere, and are known as *association* fibers (*A*, Fig. 130). The second make connection between the two hemispheres, and form

the corpus callosum. These are known as *commissural* fibers (*C*, Fig. 130). The third connect the cerebrum with the parts of the nervous system below, and are called *projection* fibers (*P*, Fig. 130).

2. *In the cerebellum* both association and commissural fibers are found. Bands of fibers, passing upward toward the cerebrum and downward toward the cord, connect this part of the brain with other parts of the nervous system.

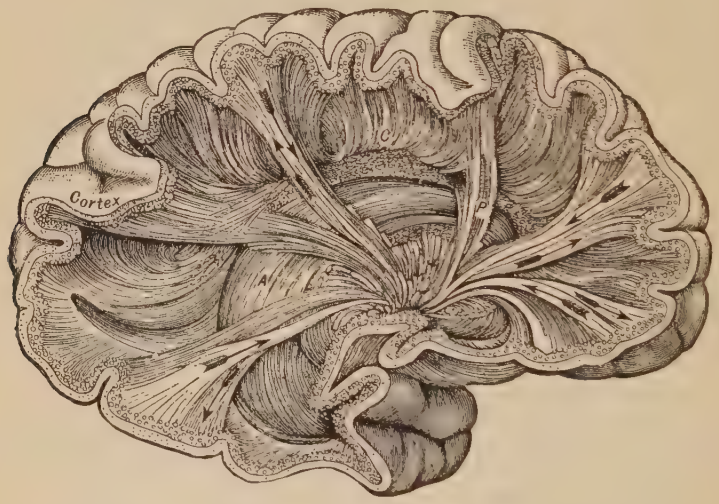

FIG. 130. — **Semi-diagrammatic representation of a section through the right cerebral hemisphere,** showing fiber tracts. *A.* Association fibers. *C.* Commissural fibers. *P.* Projection fibers. The cell-bodies with which the fiber bundles connect are in the surface layer or cortex.

3. *In the midbrain, bulb, and spinal cord* fibers are found: first, that connect these parts with the cerebrum [1] and cerebellum above; second,

[1] Fibers passing between the spinal cord and the cerebrum cross to opposite sides — most of them at the bulb, but many within the cord — so that the right side of the cerebrum is connected with the left side of the body, and *vice versa*. This accounts for the observed fact that disease or accidental injury of one side of the cerebrum causes loss of motion or of feeling in the opposite side of the body.

that pass into and become a part of the nerves of the body; and third, that connect the opposite sides of these parts together.

The Peripheral Division. — The peripheral division of the nervous system includes all the nervous structures found outside of the brain and spinal cord. These consist of the cranial, spinal, and sympathetic nerves, and of various small ganglia, all of which are closely connected with the central system.

Spinal Nerves and Dorsal-root Ganglia. — The spinal nerves comprise a group of thirty-one pairs, which connect the spinal cord with different parts of the trunk, with the upper, and with the lower extremities. Each nerve joins the cord by two roots, these being named from their positions the *ventral*, or anterior, root and the *dorsal*, or posterior, root. The two roots blend together within the spinal cavity to form a single nerve trunk, which passes out between the vertebræ. On the dorsal root of each spinal nerve is a small ganglion which is named from its position, the *dorsal-root ganglion*. (Consult Figs. 129 and 131, and also Fig. 121.)

Double Nature of Spinal Nerves. — Charles Bell, in 1811, made the remarkable discovery that each spinal nerve is double in function. He found the portion connecting with the cord by the dorsal root to be concerned in the *production of feeling* and the portion connecting by the ventral root to be concerned in the *production of motion*. In keeping with these functions, the two divisions of the nerve are made up of different kinds of fibers, as follows:

1. The dorsal-root divisions, of the fibers of afferent neurons, the cell-bodies of which form the dorsal-root ganglia (Fig. 131).

2. The ventral-root divisions, of the fibers of efferent

neurons, the cell-bodies of which are in the gray matter of the cord (p. 294).

The first convey impulses to the cord from the skin and other outlying parts; the second convey impulses from the cord to the muscles.[1] Thus by forming a part of the nerve pathways between the skin and the brain, the dorsal divisions of these nerves aid in the production of feeling; and by completing pathways to the muscles, the ventral divisions aid in the production of motion (Figs. 125, 131, and 136). The spinal nerves are all on the same plan.

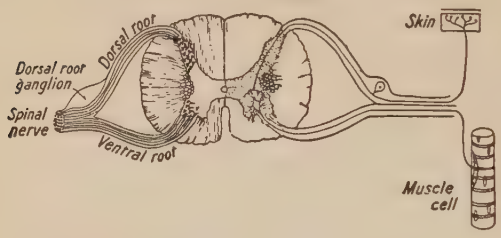

FIG. 131. — **Connection of spinal nerves with the cord.** On the right is shown a nerve pathway from the skin to the muscle. A division of this pathway not shown reaches the brain.

The Cranial Nerves. — From the under front surface of the brain, twelve pairs of nerves emerge and pass to the head, neck, and upper portions of the trunk. These, the cranial nerves, have names suggestive of their function or distribution and, in addition, are given numbers which indicate the order in which they leave the brain (Fig. 132). Unlike the spinal nerves, the cranial nerves present great variety among themselves, scarcely any two pairs being alike in function or in their connection with different parts of the body. Several of them have to do with the special senses, and are for this reason very important. They

[1] This arrangement deserves careful study. It provides a means whereby anything acting upon the skin can excite the muscles. The physiology of the nervous system, as explained in the next chapter, depends upon this arrangement.

connect the brain with the different parts of the head, neck, and trunk, as follows:

1. The first pair (*olfactory* nerves; nerves of smell; afferent) connect with the mucous membrane of the nostrils (Fig. 132).

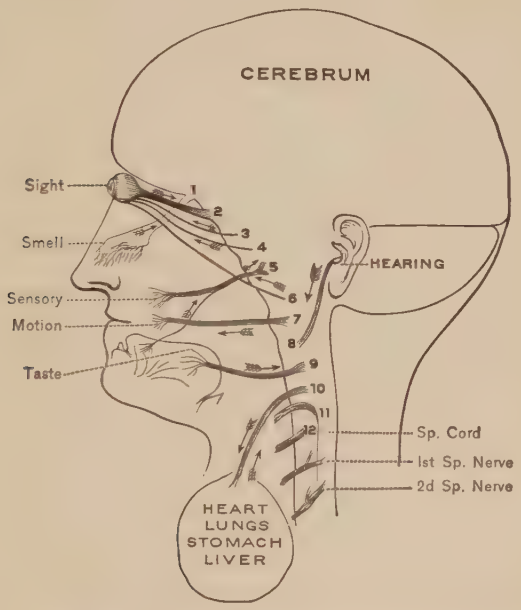

FIG. 132.— **Diagram suggesting the distribution and functions of the cranial nerves** (Colton). See also Fig. 128.

2. The second pair (*optic* nerves; nerves of sight; afferent) connect with the retina of the eyes.

3. The third, fourth, and sixth pairs (*motores oculi;* control muscles of the eyes; efferent) connect with the internal and external muscles of the eyeballs (Fig. 132).

4. The fifth pair (*trigeminal* nerves; nerves of feeling

to the face, of taste to the front of the tongue, and of control of muscles of mastication; afferent and efferent) connect with the skin of the face, the mucous membrane of the mouth, the teeth, and the muscles of mastication.

5. The seventh pair (*facial* nerves; control muscles that give the facial expressions; efferent) connect with the muscles just beneath the skin of the face.

6. The eighth pair (*auditory* nerves; nerves of hearing; afferent) connect with the internal ear.

7. The ninth pair (*glossopharyngeal* nerves; nerves of taste to back of tongue and of muscular control of pharynx; afferent and efferent) connect with the back surface of the tongue and with the muscles of the pharynx.

8. The tenth pair (*vagus*, or pneumogastric, nerves; nerves of feeling and of muscular control; afferent and efferent) connect with the heart, larynx, lungs, and stomach. They have the widest distribution of any of the cranial nerves.

9. The eleventh pair (*spinal accessory* nerves; control muscles of neck; efferent) connect with the muscles of the neck.

10. The twelfth pair (*hypoglossal* nerves; control muscles of the tongue; efferent) connect with the muscles of the tongue.

Sympathetic Ganglia and Nerves. — The sympathetic ganglia are found in different parts of the body, and vary in size from those which are half an inch in diameter to those that are smaller than the heads of pins. The largest and most important ones are found in two chains which lie in front, and a little to either side, of the spinal column, and extend from the neck to the region of the pelvis (Figs. 121 and 129). The number of ganglia in each of these chains is about twenty-four. They are connected

on either side by the right and left sympathetic nerves which extend vertically from ganglion to ganglion. In addition to the ganglia forming these chains, important ones are found in the head (outside of the cranial cavity) and in the plexuses of the thorax and the abdomen.

The sympathetic ganglia receive nerves from the central division of the nervous system, but connect with glands, blood vessels, and the intestinal walls through fibers from their own cell-bodies. Some of these latter fibers join the spinal nerves, and some blend with each other to form small sympathetic nerves.

Protection of Brain and Spinal Cord. — On account of their delicate structure, the brain and spinal cord require the most complete protection. In the first place, they are surrounded by the bones of the head and spinal column; these not only shield them from the direct effects of physical force, but by their peculiar construction prevent, to a large degree, the passage of jars and shocks to the parts within. In the second place, they are surrounded by three separate membranes, as follows:

1. The *dura*, or dura mater, a thick, dense, and tough membrane which lines the bony cavities and forms supporting partitions.

2. The *pia*, or pia mater, a thin, delicate membrane, containing numerous blood vessels, that covers the surface of the brain and cord.

3. The *arachnoid*, a membrane of loose texture, that lies between the dura and the pia.

Finally, within the spaces of the arachnoid is a lymph-like liquid which completely envelops the brain and the cord, and which, by serving as a watery cushion, protects them from jars and shocks. Thus the brain and cord are directly shielded by bones, by membranes, and by the

liquid which surrounds them. They are also protected from jars resulting from the movements of the body by the general elasticity of the skeleton.

Summary. — The nervous system establishes connections between all parts of the body, and provides a stimulus by means of which they are controlled. It is made up of a special form of cells, called neurons. The neurons form the different divisions of the nervous system, and also serve as the active agents in carrying on its work. Through a side-by-side method of joining they form the nerves, ganglia, spinal cord, and brain; and by a method of end-to-end joining they connect places remote from each other, and provide for nervous movements through the body. The nervous system may in some respects be compared to a complicated system of telephony, in which the chains of neurons correspond to the wires, and the brain and spinal cord to the central station.

Exercises. — 1. Give the meaning of the term "coördination." Supply illustrations.

2. What two general conditions are supplied in the body by the nervous system?

3. Compare the skeleton outline of the nervous system with the bony skeleton.

4. Sketch outlines of afferent and efferent neurons.

5. Give two differences between the neurons and the other cells of the body.

6. Describe the two general methods of connecting neurons in the body. What purpose is accomplished by each method?

7. Name and locate the principal divisions of the nervous system.

8. Draw an outline of the brain (side view), locating each of its principal divisions.

9. If a pencil were placed over the ear, what portions of the brain would be above it and what below?

10. Describe briefly the cerebrum, the cerebellum, the midbrain, the pons, and the bulb.

11. Locate and describe the cortex. State purpose of the convolutions.

12. State the general differences between the cranial and the spinal nerves.

13. Locate and give the number of the dorsal-root ganglia. Locate and give the approximate number of the sympathetic ganglia.

14. Show how the two portions of the spinal nerves are formed — the one from afferent and the other from efferent neurons.

15. Enumerate the different agencies through which the brain and spinal cord are protected.

16. What cranial nerves contain afferent fibers? What ones contain efferent fibers? What ones contain both afferent and efferent fibers?

17. In what respects is the nervous system similar to a system of telephony? In what respects is it different?

PRACTICAL WORK

A prepared nervous system of a frog (as obtained from some supply house) may be examined in this study. Observe the appearance and general distribution of the nerves and their connection with the brain and spinal cord. If such a preparation is not at hand, some small animal may be dissected to show the main divisions of the nervous system.

Location of Nerves in the Body. — Several of the nerves of the body lie sufficiently near the surface to be located by pressure and are easily recognized as sensitive cords. Slight pressure from the fingers reveals the presence of nerves in the grooves of the elbow (the crazy bone), between the muscles on the inner side of the arm near the shoulder, and in the hollow part of the leg back of the knee. These are all large nerves. Small nerves may be located in the same manner in the face and neck.

CHAPTER XXV

PHYSIOLOGY OF THE NERVOUS SYSTEM

In the preceding chapter was pointed out the method by which the different parts of the body are brought into communication by the neurons or nerve cells. We are now to study the means whereby the neurons are made to control and coördinate the different parts of the body and bring about the necessary adjustment of the body to its surroundings. This work of the neurons naturally has some relation to their properties.

Properties of Neurons. — The work of the neurons seems to depend mainly upon two properties — the property of irritability and the property of conductivity. *Irritability* was explained, in the study of the muscles (page 252), as the ability to respond to a stimulus. It has the same meaning here. The neurons, however, respond more readily to stimuli than do the muscles and are therefore more irritable. Moreover, they are stimulated by all the forces that induce muscular contraction and by many others besides. They are by far the most irritable portions of the body.

Conductivity is the property which enables the effect of a stimulus to be transferred from one part of a neuron to another. On account of this property, an excitation, or disturbance, in any part of a neuron is conducted or carried to all the other parts. Thus a disturbance at the distant ends of the dendrites causes a movement toward the cell-body and, reaching the cell-body, the disturbance is

passed through it into the axon. This movement through the neuron is called the *nervous impulse.*

Purpose of the Impulse. — Though the nature of the nervous impulse is not understood,[1] its purpose is quite apparent. It is the means employed by the nervous system for controlling and coördinating the different parts of the body. The arrangement of the neurons enables impulses to be started in certain parts of the nervous system, and the property of conductivity causes them to be passed *as stimuli* to other parts. This enables excitation at one place to bring about action at another place.

Acting as stimuli, the impulses seem able to produce two distinct effects: first, to throw resting organs into action and to increase the activity of organs already at work; and second, to diminish the rate, or check entirely, the activity of organs. Impulses producing the first effect are called *excitant* impulses; those producing the second effect, *inhibitory* impulses.

Functions of the Parts of Neurons. — The *cell-body* serves as a nutritive center from which the other parts derive nourishment. Proof of this is found in the fact that when any part of the neuron is separated from the cell-body, it dies, while the cell-body and the parts attached to the cell-

[1] At different times the nervous impulse has been regarded as a current of electricity; as a progressive chemical change, likened to that in a burning fuse; as a mechanical vibration, such as may be passed over a stretched rope; and as a molecular disturbance accompanied by an electrical discharge. The velocity of the nervous impulse, which is only about one hundred feet per second, proves that it is not a current of electricity. It takes place with little or no exhaustion of the cell protoplasm and consequently is not due to chemical action. And the loose, relaxed condition of the nerves prevents their transmission of physical vibrations, like those on a stretched rope. The view that the impulse is a progressive molecular disturbance, accompanied by an electrical discharge, has much evidence in its favor, but it has only recently been proposed and is likely to be modified upon fuller investigation.

body may continue to live. In addition to this the cell-body probably reënforces the nervous impulse.

The *dendrites* serve two purposes: first, they extend the surface of the cell-body, thereby enabling it to absorb a greater amount of nourishment from the surrounding lymph; second, they act as *receivers of stimuli* from other neurons. The same impulse does not pass from one neuron to another. An impulse in one neuron, however, is able to excite the neuron with which it makes an end-to-end connection (synapse), so that a series of impulses is produced along a given nerve path (Fig. 125).

The special *function of the axon* is to transmit the impulse. By its length, structure, and property of conductivity it is especially adapted to this purpose. The axis cylinder, however, is the only part of the axon concerned in the transmission. The primitive sheath and the medullary layer protect the axis cylinder, and, according to some authorities, serve to insulate it. The medullary sheath may also aid in the nourishment of the axis cylinder.

Nerve Stimuli. — While the properties of irritability and conductivity supply a necessary cause for the production and transmission of nervous impulses, these alone are not sufficient to account for their origin. An additional cause is necessary — a force not found in the nerve protoplasm, but one which, by its action on the protoplasm, makes it produce the impulse. In this respect, the neuron does not differ essentially from the cell of a muscle. Just as the muscle cell requires a stimulus to make it contract, so does the neuron require a stimulus to start the impulse. Hence, in accounting for the activities of the body, it is not sufficient to say they are caused by nervous impulses. We must also investigate the *nerve stimuli* — the means through which the nervous impulses are started. Most of these

are found outside of the body and are known as external stimuli.

Action of External Stimuli. — In the arrangement of the nervous system the most favorable conditions are provided for the reception of external stimuli. Not only do vast numbers of neurons terminate at the surface of the body,[1] but they connect there with delicate structures, called *sense organs*. The purpose of the sense organs is to *sensitize* (make sensitive) the terminations of the neurons. This they do by supplying special structures through which the stimuli can act to the best advantage upon the nerve endings. Moreover, there are different kinds of sense organs, and these cause the neurons to be sensitive to different kinds of stimuli. Acting through the sense organs adapted for receiving them, light, sound, heat, cold, and odors all act as stimuli for starting impulses. Indeed, the arrangement is so complete that the nervous system is subjected to the action of external stimuli in some form practically all the time. The work of the sense organs is further considered in Chapters XXVII, XXVIII, and XXIX.

How External Stimuli act on Internal Organs. — For stimulating the neurons not connected with the body surface we are dependent, so far as known, upon the nervous impulses. An impulse started by the external stimulus goes only so far as its neuron extends. But it serves as a stimulus for the neuron with which the first connects and starts an impulse in this connecting neuron, the point of stimulation being the synapse, the place where the terminations of the dendrites and axons come into close relation. This impulse in turn stimulates the next neuron, and so on, producing a series of impulses along a given nerve path.

[1] The surface of the body includes the linings of the air passages, food canal, and certain cavities, as well as the external covering or skin.

In this way the effect of an external stimulus may reach and bring about action in any part of the body. This is in brief the general plan of inducing action in the various organs of the body. This plan, however, is varied according to circumstances, and at least three well-defined forms of action are easily made out. These are known as *reflex action, voluntary action,* and *secondary reflex action.*

Reflex Action. — When some sudden or strong stimulus acts upon the nerve terminations at the surface of the body, an immediate response is frequently observed in

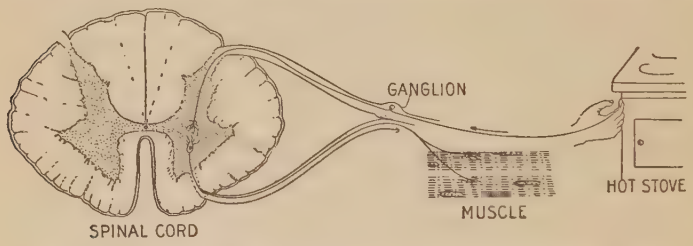

FIG. 133. — **Diagram illustrating reflex action of an external organ.**

some quick movement. The jerking away of the hand on accidentally touching a hot stove, the winking of the eyes on sudden exposure to danger, and the quick movements from slight electrical shocks are familiar examples. The explanation of reflex action is that external stimuli start impulses in neurons terminating at the surface of the body and these, in turn, excite impulses in neurons which pass from the spinal cord or brain to the muscles (Fig. 133). Since there is an apparent turning back of the impulses by the cord or brain, the resulting movements are termed *reflex.*[1]

Reflex Action and the Mind. — If one carefully studies the reflex actions of his own body, he will find that they

[1] Derived from the Latin *re*, back, and *flectere*, to turn or bend.

occur at the time, or even a little before the time, that he realizes what has happened. If a feather is brought in contact with the more sensitive parts of the face of a sleeping person, there is a twitching of the skin and sometimes a movement of the hand to remove the offending substance. Surgeons operating upon patients completely under the influence of chloroform, and therefore completely unconscious, have observed strong reflex actions. These and other similar cases indicate clearly that reflex action occurs *independently* of the mind — that the mind neither causes nor controls it. If a further proof of this fact were needed, it is supplied by experiments upon certain of the lower animals,[1] which live for a while after the removal of the brain. These experiments show that the nervous impulses that produce reflex action need only pass through the spinal cord and do not reach the cerebrum, the organ of the mind.

The Reflex Action Pathway. — By study of the impulses that produce any reflex action, a rather definite pathway may be made out, having the following divisions:

1. *From the surface of the body to the central nervous system* (usually the spinal cord). This, the *afferent* division, is made up of afferent neurons, and these have (in the case of the spinal nerves) their cell-bodies in the dorsal root ganglia (page 307). They are acted upon by external stimuli, while their impulses in turn act on the neurons in the spinal cord.

[1] A frog from which the brain has been removed is suspended with its feet downward and free to move. If a toe is pinched, the foot is drawn away, and if dilute acid, or a strong solution of salt, is placed on the tender skin, the feet are moved as if to take away the irritating substance. This of course shows that reflex action can take place independently of the brain.

Now if the spinal cord is also destroyed, there is no response when the irritation of the skin is repeated. The animal remains perfectly quiet, because the destruction of the cord has interrupted the reflex action pathway. This shows that some part of the central nervous system is necessary to reflex action.

2. *Through the central system* (spinal cord or base of brain). This, the *intermediate* division, may be composed of intermediate neurons, or it may consist of branches from the afferent neurons. In the case of separate neurons, these are acted upon by impulses from the afferent neurons, while their impulses serve in turn as stimuli to other neurons within the cord (Fig. 125).

3. *From the central nervous system to the muscles.* This, the *efferent* division, is made up of efferent neurons. Most of these have their cell-bodies in the gray matter of the cord, while their fibers pass into the spinal nerves by the ventral roots.[1] They may be stimulated by impulses either from the intermediate neurons, or from branches of the afferent neurons. Their impulses reach and stimulate the muscles.

Reflex Action in Digestion. — The flowing of the saliva, when food is present in the mouth, is an example of reflex action. In this case, however, the organ excited to activity is a gland instead of a muscle. The food starts the impulses, and these, acting through the bulb, reach and stimulate the salivary glands. In a similar manner food excites the glands that empty their fluids into the stomach and intestines, and stimulates the muscular coats of these organs to do their part in the digestive process. To a considerable extent, neurons having their cell-bodies in the sympathetic ganglia are concerned in these actions (Fig. 134).

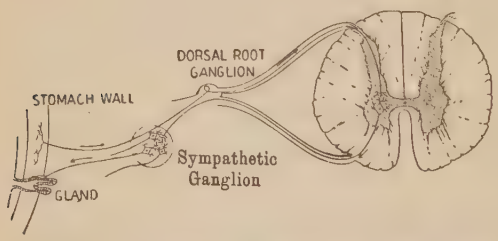

FIG. 134. — **Diagram illustrating reflex action** in its relation to the food canal. The nerve path in this case includes sympathetic neurons.

Reflex Action in the Circulation of the Blood. — On sudden exposure

[1] Review description of the spinal nerves, page 307.

to cold, the small arteries going to the skin quickly diminish in size, check the flow of blood to the surface, and prevent too great a loss of heat. In this case, impulses starting at the surface of the body are transmitted to the bulb and then through the efferent neurons to the muscles in the walls of the arteries. In a somewhat similar manner, heat leads to a relaxation of the arterial walls and an increase in the blood supply to the skin. Other changes in the blood supply to different parts of the body are also of the nature of reflex actions. As in the work of digestion, neurons having their cell-bodies in the sympathetic ganglia aid in the control of the circulation.

Purposes of Reflex Action. — The examples of reflex action so far considered illustrate its two main purposes — (1) protection, and (2) a means of controlling important processes.

The pupil has but to study carefully the reflex actions of his own body for a period, say of two or three weeks, in order to be convinced of their protective value. He will observe that portions of his body have, on exposure to danger, been moved to places of safety, while in some instances, like falling, his entire body has been adjusted to new conditions. He will also find that reflex action is quicker, and for that reason offers in some cases better protection, than movements directed by the mind. In digestion and circulation are found the best examples of the control of important processes through reflex action.

Voluntary Action. — It is observed that reflex action, in the sense that it has so far been considered, is not the usual mode of action of the external organs, but is, instead, a kind of emergency action, due to unusual conditions and excitation by strong stimuli. Voluntary actions, on the other hand, represent the ordinary, or normal, action of these organs. They comprise the movements of the body of which we are conscious and which are *controlled by the mind.* But while they are of a higher order than reflex

actions and are under *intelligent* direction, they are brought about in much the same manner.

Voluntary Action Pathways differ in but one essential respect from those of reflex action. They pass through the cerebrum, the organ of the mind (Fig. 135). This is necessary in order that the mind may control the action. From all portions of the body surface, afferent pathways may be traced to the cerebrum; and from the cerebrum efferent pathways extend to all the voluntary organs. A complex system of intermediate neurons, found mostly in the brain, join the afferent with the efferent pathways. The voluntary pathways are not distinct from, but include, reflex pathways, a fact which explains why the same external stimulus may excite both reflex and voluntary action (Fig. 135).

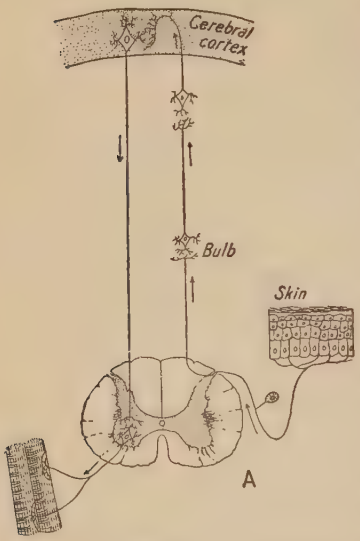

FIG. 135. — Diagram of a voluntary action pathway.

Choice in Voluntary Action. — In reflex action a given stimulus, acting in a certain way, produces each time the same result. This is not the case with voluntary action, the difference being *due to the mind.* In these actions the external stimulus first excites the mind, and the resulting mental processes — perhaps as memory of previous experiences — supply a variety of facts, any of which may act as stimuli to action Before the action takes place, however,

some one fact must be singled out from among the mental processes excited. This fact becomes the *exciting stimulus* and leads to action. It follows, therefore, that the action which finally occurs is not necessarily the result of an immediate external stimulus, but of a *selected* stimulus — one which is the result of choice.

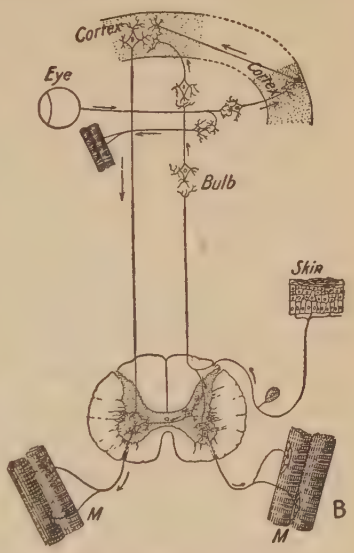

FIG. 136. — **Diagram of voluntary action pathways** including reflex pathways.

Not only does the element of choice enter into the selection of the proper stimulus, but it also enters into the time, nature, and intensity of the action. For these reasons it is frequently impossible to trace voluntary actions back to their actual stimuli. The pupil will recognize the element of choice in such simple acts as picking up some object from the street, complying with a request, and purchasing some article from a store.

Reflex and Voluntary Action Compared. — Certain likenesses and differences, already suggested in these two forms of action, may now be more fully pointed out. Reflex and voluntary action are alike in that the primary cause of each is some outside force or condition which has impressed itself upon the nervous system. They are also alike in the general direction taken by the impulses in producing the action. The impulses are, first, from the surface of the body to the central nervous system; second,

through the central system; and third, from the central nervous system to the active tissues of the body.

Their chief differences are to be found, first, in the pathways followed by the impulses, which are through the cerebrum (the organ of the mind) in voluntary action, but in reflex action are only through the spinal cord or the lower parts of the brain; and second, in the fact that voluntary action is under the direction of the mind, while reflex action is not. It would seem, therefore, that the statement sometimes made that "voluntary action is reflex action plus the mind" is not far from correct. Mind, however, is the important factor in this kind of action.

Secondary Reflex Action. — Everyday experience teaches that any voluntary action becomes easier by repetition. A given act performed a number of times under conscious direction establishes a condition in the nervous system that enables it to occur without that direction and very much as reflex actions occur. Actions of this kind are known as secondary reflex actions, or as *acquired reflexes*. Walking, writing, and numerous other movements pertaining to the occupation which one follows are examples of such reflexes. These activities are at first entirely voluntary, but by repetition they gradually become reflex, requiring only the stimulus to start them.

The advantages to the body of its acquired reflexes are quite apparent. The mind does not have to attend to the selection and direction of stimuli and, to that extent, is left free for other work. A good example of this is found in writing, where the mind apparently gives no heed to the movements of the hand and is only concerned in what is being written. Another good example is seen in the playing of some musical instrument, and still another in the driving of a car.

Acquired Reflexes and Automobile Driving. — When one is learning to drive, he must give his entire attention to the various devices for controlling the car. He must decide when to increase and when to diminish the gas, when and how to shift gears, when to put on and when to release the brakes, and how much and which way to turn the steering wheel. If he thinks of other things than his driving, he is very likely to lose control and may have an accident. But he has less and less trouble as he continues to drive. Finally the time comes when his hands and feet do just what they should without direct and conscious orders from the mind, and after he has gained this skill his driving is not only easier but much safer. The quick responses that require no thinking enable him to meet emergencies as they arise and to avoid accidents.

Habits. — People are observed to act differently when exposed to the same conditions, or when acted upon by the same stimuli. This is explained by saying they have different habits. By *habits* are meant certain general modes of action that have been acquired by repetition. Certain acts repeated again and again have established conditions in the nervous system which enable definite forms of action to be excited, somewhat after the manner of reflex action. On account of habits, therefore, the actions of the individual are more or less *predisposed*. What he will do under certain conditions may be foretold from his habits. Habits simply represent a higher order of secondary reflexes — those more closely associated with the mental life and character than are the lower forms.

Habits, in common with other forms of secondary reflex action, serve the important purpose of *economizing the nervous energy*. However, if pernicious habits are formed instead of those that are useful, they are detrimental from both a moral and a physical standpoint. Youth is recognized as the period in which fundamental habits are formed and character is largely determined. Therefore parents

and teachers do wisely when they insist upon the formation of right habits by the young.

Functions of Divisions of the Nervous System. — The relationship between the different parts of the nervous system is very close and one part does not work independently of other parts. At the same time the general work of the nervous system requires that its different divisions serve different purposes:

1. The peripheral divisions of the nervous system are concerned in the transmission of impulses between the surface of the body and the central system and between the central system and the active tissues. The nerves are the carriers of the impulses. The ganglia contain the cell-bodies which serve as nutritive centers; and, in the case of the sympathetic ganglia, these cell-bodies are the places where the fiber terminations of one neuron connect with, and stimulate, other neurons.

2. The gray matter in the spinal cord, bulb, pons, and midbrain (through the cell-bodies, fiber terminations, and short neurons which they contain) completes the reflex action pathways between the surface of the body and the voluntary muscles, and also between the surface of the body and the organs of circulation and digestion.

3. The white matter of the spinal cord, bulb, pons, and midbrain (by means of the fibers of which they are largely composed) forms connections with, and passes impulses between, the various parts of the central nervous system.

4. The bulb, because of certain special reflex-action pathways completed through it, is the portion of the central nervous system concerned in the control of respiration, circulation, and the secretion of liquids.

Work of the Sympathetic Ganglia and Nerves. — The neurons which form these ganglia aid in controlling the vital processes, especially di-

gestion and circulation. These neurons are controlled for the most part by fibers from the bulb and spinal cord, and cannot for this reason be looked upon as forming an independent system. Their chief purpose seems to be that of spreading the influence of neurons from the central system over a wider area than they would otherwise reach. For example, a single neuron passing out from the spinal cord may, by terminating in a sympathetic ganglion, stimulate a large number of neurons, each of which will in turn stimulate the cells of muscles or of glands. Because of this function, the sympathetic neurons are sometimes called *distributing* neurons.

Functions of the Cerebellum. — Efforts to discover some *special* function of the cerebellum have been in the main unsuccessful. Its removal from animals, instead of producing definite results, usually interferes in a mild way with a number of activities. The most noticeable results are a general weakness of the muscles and an inability on the part of the animal to balance itself. This and other facts, including the manner of its connection with other parts of the nervous system, have led to the belief that the cerebellum is the chief organ for the *reflex* coördination of muscular movements, especially those having to do with the balancing of the body. In this connection it is subordinate to and under the control of the cerebrum. Of the relations which the cerebellum sustains to the cerebrum and to the different parts of the body, the following view is quite generally held:

In the development of secondary reflexes, as already described, conditions are established in the cerebellum, such that given stimuli may act *reflexively* through it and produce definite results in the way of muscular contraction. After the establishment of these conditions, afferent impulses from the eyes, ears, skin, and other places, under the general direction of the cerebrum, may cause such actions as the balancing of the body, walking, etc., as well as the delicate and varied movements of the hand. This view of its functions makes of the cerebellum the great center of secondary reflex action.

Functions of the Cerebrum. — While the work of the cerebrum is closely related to that of the general nervous system, it, more than any other part, exercises functions peculiar to itself. The cerebrum is the part of the nervous system upon which our varied experiences leave their impressions and through which these impressions are made

to influence the movements of the body. But the power to alter, postpone, or entirely inhibit, nervous movements is but a part of the general work ascribed to the cerebrum as *the organ of the mind.* Numerous experiments performed upon the lower animals, together with observations on man, show the cerebrum to be the seat of the mental activities, and to make possible, in some way, the processes of consciousness, memory, volition, imagination, emotion, thought, and sensation.

Localization of Cerebral Functions. — Many experiments have been performed with a view to determining whether the entire cerebrum is concerned in each of its several activities or whether special functions belong to its different parts. These experiments have been made upon the lower animals and the results thus obtained compared with observations made upon injured and imperfectly developed brains in man. The results have led to the conclusion that certain forms of the work of the cerebrum are *localized* and that some of its parts are concerned in processes different from those of others.

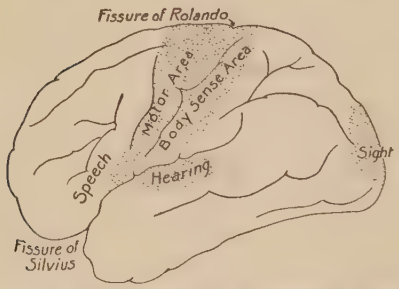

FIG. 137. — **Location of cerebral functions.** Diagram of cerebrum, showing most of the areas whose functions are known.

The work of locating the functions of different parts of the cerebrum forms one of the most interesting chapters in the history of brain physiology. The portions having to do with sight, bodily feeling, voluntary motion, speech, and hearing have been rather accurately determined, while considerable evidence as to the location of other functions has been secured. Much of the cerebral surface, however, is still undetermined (Fig. 137).

NERVOUS CONTROL OF IMPORTANT PROCESSES

Circulation of the Blood. — 1. *Control of the Heart.* — The ability to contract at regular intervals has been shown to reside in the heart

muscle. Among other proofs is that furnished by cold-blooded animals, like the frog, whose heart remains active for quite a while after its removal from the body. These automatic contractions, however, are not sufficient to meet all the demands made upon the circulation. The needs of the tissues for the constituents of the blood vary with their activity, and it is therefore necessary to vary frequently the force and rapidity of the heart's contractions. Such changes the heart itself is unable to bring about.

For the purpose of controlling the rate and force of its contractions, the heart is connected with the central nervous system by two kinds of fibers:

a. Fibers that convey *excitant* impulses to the heart to quicken its movements.

b. Fibers that convey *inhibitory* impulses to the heart to retard its movements.

The cell-bodies of the excitant fibers are found in the sympathetic ganglia, but fibers from the bulb connect with and control them. The cell-bodies of the inhibitory fibers are located in the bulb, from where their fibers pass to the heart as a part of the vagus nerve.

In addition to the fibers above mentioned, are those that convey impulses *from* the heart to the bulb. These connect with neurons that in turn connect with blood vessels and with them act reflexively, when the heart is likely to be overstrained, to cause a dilation of the blood vessels. This lessens the pressure which the heart must exert to empty itself of blood. These fibers serve, in this way, as a kind of safety valve for the heart.

2. *Control of Arteries.* — Changes in the rate and force of the heart's contractions can be made to correspond only to the *general* needs of the body. When the blood supply to a particular organ is to be increased or diminished, this is accomplished through the muscular coat in the arteries. The connection of the arterial muscle with the sympathetic ganglia and the method by which they vary the flow of blood to different organs has already been explained (pages 321 and 51), so that only the location of the controlling neurons need be noted here. These, like the controlling neurons of the heart, have their cell-bodies in the bulb. It thus appears that the entire control of the circulation is effected in a reflex manner through the nerve centers in the bulb. These centers are stimulated by conditions that relate to the movement of the blood through the body.

Respiration. — Efferent fibers connect the different muscles of respiration with a cluster of cell-bodies in the bulb, called the *respiratory center*. This center together with the nerves and muscles in question form an automatic, or self-acting, mechanism similar in some respects to that of the heart. Through the impulses passing from the respiratory center to the muscles, a rhythmic action is maintained sufficient to satisfy the usual needs of the body for oxygen. The demand of the body for oxygen, however, varies with its activities, and to such variations the respiratory center alone is unable to respond. The regulating factor in the respiratory movements has been found to be the condition of the blood with reference to the presence of oxygen and carbon dioxide. If the blood contains much carbon dioxide and little oxygen, it acts as a strong stimulus to the respiratory center, causing it, in turn, to stimulate the respiratory muscles with greater intensity and frequency. On the other hand, if the blood contains much oxygen and little carbon dioxide, it acts only as a mild stimulus. This explains how physical exercise increases the breathing, since the muscles at work consume more oxygen than when resting and give more carbon dioxide and other wastes to the blood.

The respiratory center is also connected by afferent nerves with the mucous membrane of the air passages. Irritation of the nerve endings in this membrane causes impulses to pass to the center, and this leads, by reflex action, to such modifications of the respiratory acts as sneezing and coughing. There is also a connection between the cerebrum and the respiratory center. This is shown by the fact that one can voluntarily change the rate and force of the respiratory movements, and further by the fact that emotions affect the breathing.

Regulation of the Body Temperature. — As explained in the study of the skin (page 282), the nervous system regulates the body temperature by controlling the circulation of the blood through the skin and the internal organs. This is accomplished by stimulating in a reflex manner the muscles in the walls of certain arteries. To prevent the body from getting too hot, muscles in the arteries going to the skin relax, thereby allowing more blood to flow to the surface, where the heat can be disposed of through radiation and through the evaporation of the perspiration. On the other hand, if the body is in danger of losing too much heat, the muscles in the walls of arteries going to the skin are made to contract and those to internal organs to relax, so that less blood flows to the skin and more to the internal organs.

Summary. — The nervous system is able to control, coordinate, and adjust the different organs of the body through its intimate connection with all parts and through a stimulus (the nervous impulse) which it supplies and transmits. Nervous impulses, excited by external stimuli, follow definite paths and cause activity in the different parts of the body. All such pathways are through the central nervous system. In reflex action the impulses are mainly through the spinal cord, but to some extent through the bulb, pons, and midbrain. In voluntary action they pass through the cerebrum — a condition that leads to important modifications in the results. The cerebrum, in addition to controlling the voluntary movements, is able to establish the necessary conditions for secondary reflex actions, such as walking, writing, etc. All parts of the nervous system are closely related.

Exercises. — 1. Give the function of each of the parts of a neuron.

2. State the purpose of the nervous impulse.

3. Show that the exciting cause of bodily action is outside of the nervous system and, to a large extent, outside of the body.

4. Describe the arrangement that enables stimuli outside of the body to cause action within the body.

5. Describe a reflex action and show how it is brought about.

6. Distinguish between afferent, efferent, and intermediate neurons.

7. Draw diagrams showing the impulse pathways in voluntary and in reflex action.

8. What purposes are served by the sympathetic neurons?

9. Describe the method of control of the circulatory and digestive processes. How do reflex actions protect the body?

10. Compare voluntary and reflex action. In what sense are all the activities of the body reflex?

11. In what sense is walking voluntary? In what sense is it reflex?

12. How does secondary reflex action lessen the work of the nervous system?

PRACTICAL WORK

To Demonstrate Nerve Pathways. — A smooth board, 2 × 6 ft., is painted black, and upon this is drawn in white a life-size outline of the body. Pieces of cord of different colors and lengths are knotted to represent the afferent and efferent neurons. These are then pinned or tacked to the board in such a manner as to represent the connections in the different kinds of nerve pathways. Figure 138 shows such a board with connections for a reflex action and a voluntary action of the same muscle.

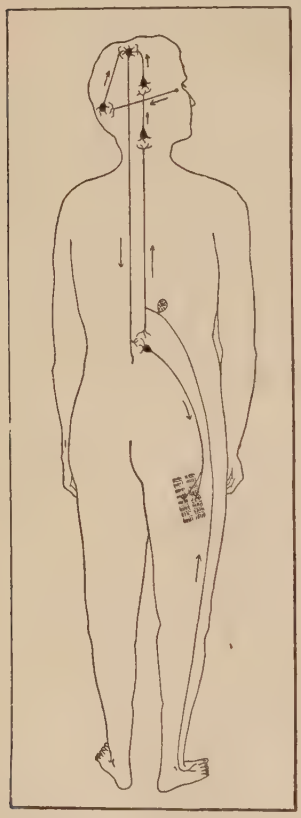

FIG. 138. — **Nerve board** for demonstrating nerve pathways.

Study of the "Knee Jerk" Reflex. — A boy is seated on a chair with the legs crossed. With a small stick or ruler he is given a quick blow on the short tendon which passes from the lower margin of the knee-cap to the tibia. The stroke will usually be followed by a reflex movement of the foot.

Other reflex actions adapted to class study are those of the eyes, such as the closing of the lids on moving objects near them and the dilating of the pupils when the eyes are shaded.

Reflex Action of the Salivary Glands. — Place a small pinch of salt upon the tongue and note the flow of saliva into the mouth. Try other substances, as starch, bits of wood, and sugar. What appears to be the natural stimulus for these glands? Compare with reflex actions of the muscles.

CHAPTER XXVI

HYGIENE OF THE NERVOUS SYSTEM

NATURALLY we would expect our methods of living to have a profound effect upon the most delicate of our bodily structures. Right living as regards the nervous system would protect it from mechanical injuries, from poisonous and habit-forming drugs, from conditions within the body that injure the nerves, and from overdrafts upon the nervous energy. The serious disorders of the nervous system, including insanity and paralysis, usually have their beginnings in the little things of everyday living.

The Main Problem. — Many of our nervous disorders are undoubtedly due to the age in which we live. Our modern civilization, with all its facilities for human advancement and enjoyment, throws an extra strain upon the nervous system. Educational and social standards are higher than ever before and life in all its phases is more complex. Since we can hardly change the conditions under which we live, and probably would not if we could, we must learn to adapt or adjust ourselves to them so as to secure for the nervous system such relief as it requires. This adjustment is sometimes difficult, even when the actual needs of the nervous system are known.

The healthful action of the nervous system requires, on the one hand, exercise, but on the other hand, a certain condition of quietude, or *poise* — a state which is directly opposed to that of restlessness. The conditions of modern

life seem able to force upon the nervous system all the exercise that it needs, and more (whether it be of the right kind or not), so that the main problem of to-day seems to be that of conserving, or economizing, the nervous energy and of preventing nervous waste.

Wasteful Forms of Nervous Activity. — There are without doubt many forms of activity that waste the vital forces of the body and lead to nervous exhaustion. Take, for example, the rather common habit of worrying over the trivial things of life. Certainly the nervous energy spent in this way cannot be used in doing useful work, but must be counted as so much loss to the body. One who would use his nervous system to the best advantage must find some way of preventing waste of this kind.[1]

Undue excitement, as well as pleasurable dissipations, also tend toward nervous exhaustion. And while the fact is recognized that pleasurable activities supply a necessary mental exercise, the limit of healthful endurance must be watched and *excesses of all kinds avoided.* Intense emotional states are found to be exhausting in the extreme; and the suppression of such undesirable feelings as anger, fear, jealousy, and resentment are of immense value in the hygiene of the nervous system.

The Habit of Self-control. — Much of the needless waste of nervous energy, including that of worrying over trivial matters, may be prevented through the exercise of self-control. From the standpoint of the nervous system, the present age differs from the past mainly in supplying a

[1] Where a deep-seated cause for worry exists, there may be occasion for grave concern. Many people have become insane through continued worry about some *one* thing. In cases of this kind the sufferer needs the aid of sympathetic friends, and sometimes of the physician, in getting the mind away from the exciting cause. A change of scene, a visit, or some new employment is frequently recommended, where the actual cause for the worry cannot be removed.

greater number and variety of nerve stimuli. Self-control means the ability to suppress activities that would result from undesirable stimuli and to direct the bodily activities into channels that are profitable. Self-control, therefore, is not only to be exercised on occasions of great emergency, but in the everyday affairs of life as well. It is even more important that the daily toiler at his task be able to keep the petty annoyances of life from acting as irritants to his nervous system than that he keep cool during some great calamity. The habit of self-control is acquired mainly through the persistent effort to prevent any and all kinds of petty annoyances from affecting the nerves or the temper.

Nervousness. — Self-control is much more easily practiced by some than by others. This is due partly to habit, but is also due to an actual difference in the degree of sensitiveness, or irritability, of the nervous systems of different people. One whose nervous system tends to respond too readily to any and all kinds of stimuli is said to be "nervous." This condition is in some instances inherited, but is in most cases due to the wasteful expenditure of nervous energy or to the action of some drug upon the body. Excess of mental work, too much reading, long-continued anxiety, eye strain, and the use of tea, coffee, alcohol, tobacco, or other drugs, including many of those taken as medicines, are known to cause nervousness. Nervousness is not only a source of great annoyance, both to one's self and to others, but is a menace to the general health.

The first step toward securing relief from such a condition is the removal of the cause. The habits should be inquired into and excesses of all kinds discontinued. In some instances it may be necessary to have a physical

examination made in order to discover bodily conditions or habits that may cause the nervous weakness.

Bodily Conditions that act Harmfully upon the Nervous System. — These include,

1. *Strain of the eyes.* This is perhaps the most widely prevalent and serious of the causes of nervousness, headache, and other symptoms that result from a run-down state of the nerves. More than half of all headaches are from eyestrain. On this account nothing may be more important for the nervous person than a well-fitted pair of glasses.

2. *Decayed and impacted teeth* and other bad conditions of the mouth as explained in Chapter XIV.

3. *Infections in any part of the body.* The poisons secreted by germs are very harmful to the nerves, and germs themselves may attack the nervous system.

4. *Misplaced bodily organs.*

5. *Disturbed circulation* with an excess of blood going to the brain (p. 75).

In relieving these causes, hygiene may be just as important as medicine. We should coöperate with the physician in every way possible when it is necessary to employ his services.

To Relieve Excess Flow of Blood to the Brain. — Disturbed circulation is a much more frequent cause of nervousness than is generally supposed. Though mental work and excitement tend naturally to increase the flow of blood to the brain, this should subside with rest and relief from excitement. When there is a tendency for this to become permanent, effort should be made for relief. The general method is to increase the circulation to the feet by much walking, tip-toeing exercises, warm shoes and stockings, and by sleeping with the head a little higher than the feet (p. 74).

Hygienic Value of Work. — Within reasonable limits, both mental and physical work are conducive to the vigor of the nervous system. Through work the energies of the body find their natural outlet, and this prevents dissipation and the formation of bad habits. Even hard work does not injure the nervous system, and severe mental exertion may be undergone, provided the proper hygienic conditions are observed. The nervous disorders suffered by brain workers are not, as a rule, due to the work which the brain does, but to violation of the laws of health, especially the law of exercise. Such persons should observe the general laws of hygiene and especially should they practice daily those forms of physical exercise that tend to counteract the effects of mental work.

Physical Exercise properly taken is beneficial to the nervous system through both direct and indirect effects. A large proportion of the nerve cells have for their function the production of motion, and these are called into play only through muscular activity. Then, as already suggested, physical exercise counteracts the unpleasant effects of mental work. Hard study causes an excess of blood to be sent to the brain and a diminished amount to the arms and to the legs. Physical exercise redistributes the blood and equalizes the circulation. Light exercise should, therefore, follow hard study. The student before retiring at night is greatly aided in getting to sleep and is put in a better condition for the next day's work by ten to fifteen minutes of light gymnastics. A daily walk of two or three miles is also an excellent means of counteracting the effects of mental work. The brain worker should, however, avoid violent exercise or the carrying of any kind of exercise to exhaustion.

Sleep, and plenty of it, is one of the first requirements

of the nervous system. It is during sleep that the exhausted brain cells are replenished. To shorten the time for sleep is to weaken the brain and to lessen its working force. No one should attempt to get along with less than eight hours of sleep each day and most people require more. Children require more sleep than adults. Those under six years should have from eleven to twelve hours of sleep per day. Children between six and ten years should have at least ten hours.

Insomnia, or sleeplessness, on account of its effects upon the nervous system, is to be regarded as a serious condition, and hygienic means for relieving it should be diligently sought. Having its cause in nervousness, a disturbed circulation of the brain, or some form of nervous exhaustion, it is benefited through relieving these conditions and in the manner already described. Of course the external conditions for aiding sleep should not be overlooked. The bed should be comfortable, and the room should be cool, well ventilated, dark, and quiet. The inducing of sleep by means of drugs is a dangerous practice and should never be resorted to except under the direction of the physician.

Effect of Emotional States. — We have already noted the effect of anger, worry, and strain upon the digestion of the food (p. 172). Intense emotions are also known to interfere with breathing and with the action of the heart. Such effects are explained through the close relation of the mind to the work of the nervous system in general. While certain emotional states, such as fear, anger, melancholia, and the impulse to worry, interfere seriously with the normal action of the nervous system, others, such as contentment, cheerfulness, and joy, are decidedly beneficial in their effects. On this account, one's

general mode of reaction, or disposition, is of the greatest importance to the health of the nervous system.

The Hygienic Disposition. — This may be defined as a good disposition plus some exceptionally fine qualities, such as courage, poise, optimism, self-control, and patience. The test for the hygienic disposition is the ability to keep good natured, cheerful, and hopeful *under trying circumstances*. While one with the ordinary good disposition can maintain agreeable states of mind when he is well, has everything he wants, and is well treated, the one with a hygienic disposition can keep his poise and good nature when overtaken by sickness or other misfortunes. This shows the importance of the hygienic disposition. It conserves nervous energy at times when it is most needed.

To Improve the Disposition. — Although our dispositions are molded to a considerable extent by our experiences, and especially by the way we are treated, it is also true that we can change them. If one's disposition is not as good as it should be, he can bring about marked improvements. One method of improving it is by self-discipline and the exercise of self-control, as already suggested. Another has health betterment as a basis. As we improve in health, all of our mental reactions become better. And a third applies the principle of helpfulness to others. This is expressed in the oft-quoted statement: "As we help others with their worries, we forget our own."

The Nervous Condition of Children should be a matter of deep concern on the part of both parents and teachers. In the home, as well as in the school, the child may be "pushed" until the nervous system receives permanent injury. Exhaustion of nerve cells is produced through too many and too vivid impressions being made upon the immature brain. The child should be protected from

undue excitement. He should have the benefit of outdoor exercise and should be early inured to cold. He should be shielded from the poisoning effects of tea, coffee, tobacco, alcohol, and other drugs. He should have impressed upon him the habit of self-control. He should not be indulged in foolish caprices or whims, but should be taught to be content with plain, wholesome food and with the simple forms of enjoyment.

Influences at School. — School life is necessarily a great strain upon the child. Night study added to the work of the day makes a heavy burden for elementary pupils to bear. Though the legal school age is usually fixed at six years, delicate children should be kept out of school until they are seven or eight years old, provided they have good homes. In addition to the excitation incident to studying and reciting lessons, conditions frequently arise both in the schoolroom and upon the playground that create a feeling of fear or dread in the minds of children. Quarrels and feuds among the children and the bullying of big boys on the playground may work untold harm. All conditions tending to develop fear, uneasiness, or undue excitement on the part of children should receive the attention of those in authority.

Excessive Reading is a frequent cause of injury to the nervous systems of children. This has a bad effect, both on account of too many impressions being made upon the mind and also on account of the strain to the eyes. Then if the reading consists mostly of light fiction, the mind is directed away from the really important things of life. The reading of children should be thoughtfully controlled, both as to quality and quantity. Exciting stories should, as a rule, be excluded, but a taste for biography, historical and scientific writings, and for the great works

of literature should be cultivated. Simple fairy tales which have a recognized value in developing the imagination of the child need not be omitted, but it is of vital importance that the "story-reading habit" be not formed.

Effects of Drugs. — Because of its delicacy of structure a number of chemical compounds, or drugs, are able to produce injurious effects upon the nervous system. Some of these are violent poisons, while others, in small quantities, are mild in their action. Certain drugs, in addition to their immediate effects, bring about changes in the nervous system which cause an unnatural appetite, or craving, that leads to their continued use. This is the case with alcohol, the intoxicating substance in the usual saloon drinks, and with nicotine, the stimulating drug in tobacco. The same is also true of morphine, chloral, and several other drugs used as medicines. The *danger of becoming a slave* to some useless and pernicious habit should dissuade one from the use of drugs except in cases of positive emergency.

Alcohol and the Nervous System. — Alcohol, as already shown, injures practically all portions of the body; but it has its worst effects upon the nervous system. Through its action on this system, it interferes with the circulation of the blood, produces a condition of "temporary insanity" called intoxication, weakens the will, and eventually dethrones the reason. Worst of all, it produces a condition of "chronic poisoning" which manifests itself in an unnatural craving, and this causes it to be used by the victim even when he knows he is "drinking to his own destruction." Though its use in small quantities does not, as a rule, produce such marked effects upon the nervous system, it develops the "craving," and this is apt in time to lead to its use in larger quantities. But even if this does not occur, the practice is objectionable for its unhygienic effects

in general.[1] Tippling with such mild solutions of alcohol as light wine, beer, hard cider, or "home brew" is, for these reasons, a dangerous pastime.

Alcohol and Crime. — It is sometimes stated that no one who leaves alcohol alone will be injured by it. This is true only of its direct effects; not of its indirect effects. Whenever a crime is committed somebody is injured, and alcohol is known to be a chief cause of crime. Alcohol causes crime through the loss of self-control, seen especially in intoxication, and also because of the moroseness and quarrelsomeness which it developes in certain individuals. Indirectly it causes crime through the poverty which it engenders and through its influence in bringing about social conditions out of which crime develops. Everything considered, the free use of alcohol is incompatible with the nervous health and moral tone of a community.

Nicotine and the Nervous System. — Nicotine is an oily substance which is extracted from the tobacco plant. Its action on the nervous system is in general that of a poison. Taken in small quantities, it is a mild stimulant and, if the doses are repeated, a habit is formed which is difficult to break. Tobacco is used mainly for the stimulating effect of this drug. While not so serious in its results as the alcohol and other drug habits, the use of tobacco is of no benefit, is a continual and useless expense, and, in many instances, causes a derangement of the healthy action of the body.[2]

[1] Insurance statistics show that habitual *moderate drinkers* do not live so long as abstainers.

[2] Organs very frequently affected by tobacco are the heart and the eyes. It induces, as already stated (page 71), a dangerous nervous derangement called "tobacco heart," and it causes a serious disorder of the retina (retinitis) which leads in some instances to loss of vision. Tobacco smoke also acts as an irritant to the delicate lining of the eyes, especially when the tobacco is smoked indoors.

With the bad effects of the nicotine must be included those of questionable substances added to the tobacco by the manufacturer, either for their agreeable flavor or for adulteration.

Relation of Age to the Effects of Nicotine. — The use of tobacco by the young is especially to be deplored. In addition to the harmful effects observed in those of mature years, nicotine interferes with the normal development of the body and lays, in many instances, the foundation for physical and mental weakness in later life. The cigarette is decidedly harmful, especially when inhalation is practiced, its deadening effects being in part due to the wrappers, some of which have been shown to contain arsenic and other poisonous drugs. While dulling the intellect and weakening the body, cigarette smoking also tends to make criminals of boys.[1] Parents, teachers, school officers, and all who have the good of mankind at heart should take every precaution, including that of setting a good example, to prevent the formation of the tobacco habit by those of immature years.

Habit versus Self-control. — The power of self-control, already emphasized for its importance in the economical expenditure of the nervous energy, is of vital importance in its relation to the habits of the body. Self-control is the chief safeguard against the formation of bad habits and is the only means of redemption from such habits after they have once been formed. The persistent cultivation of the power to control the appetites and the passions, as well as all forms of activity which tend to injure the body or debase the character, gives a tone to the nervous system

[1] Of 4117 boys in the Illinois State Reformatory, 4000 used tobacco, and over 3000 were cigarette smokers. Dr. Hutchison, of the Kansas State Reformatory, says: "Using cigarettes is the cause of the downfall of more of the inmates of this institution than all other vicious habits combined."

which increases the self-respect and raises the individual to a *higher plane of life*. The worst habits *can* be broken and good ones formed in their stead, if only there is sufficient determination to accomplish these results. Failure comes from not having the mind thoroughly "made up" and from not having, back of the desire to do better, "the strong will of a righteous determination."

Effects of External Conditions. — While the inner life and habits have most to do with the hygiene of the nervous system, a certain amount of attention may properly be given to those conditions outside of the body which affect directly or indirectly the state of this system. Noise, disorder, and confusion act as nervous irritants, but quiet, order, and system have the opposite effect. There is, therefore, much in the management of the office, factory, schoolroom, or home that has to do with the real hygiene of the nerves as well as with the efficiency of the work that is being done. The suppression of distracting influences not only enables the mind to be given fully to the work in hand, but actually prevents waste of nervous energy.

It is also a matter of much importance to the nervous system to keep rooms at the right temperature, neither too hot nor too cold.

Social Relations. — In considering the external conditions that affect the nervous system, the fact must not be overlooked that man is a social being and has to adjust himself to an established social order. His relations to his fellow-men, therefore, affect strongly his nervous condition and theirs also. For this reason the best hygiene of the nervous system is based upon *moral* as well as physical right living. Along with the power of self-control and the maintenance of a correct nervous poise, there should be a proper regard

for the welfare of others. On account of the ease with which one individual may disturb the nervous state of another, those social forms and customs which tend to establish harmonious relations among men are truly hygienic in their effects, and may well be carried out in spirit as well as "in letter."

It is also a fact that a given mental state in one person tends to excite a like state in those with whom he associates. How important, then, that each and all cultivate, as habits, the qualities of cheerfulness, kindness, and good-will, instead of the opposite states of mind. Especially in the family, and other groups of closely associated individuals, should the nervous effect of one member upon the others be considered and every effort made to secure and maintain harmonious relations.

The High Ideal. — Everything considered, the conditions most favorable to the healthfulness of the nervous system are in harmony with what our greatest teachers have pointed to as the higher plane of living. On this account a true conception of the value and meaning of life is of the greatest importance. *An ever present, strong desire to live a vigorous, but simple and noble, life* will suggest the proper course to pursue when in doubt and will stimulate the power of self-control. It will lead to the stopping of "nerve leaks" and to the maintenance of harmonious relations with one's fellows. It will cause one to recoil from the use of alcohol and other nerve poisons, as from a deadly serpent, seeing the end in the beginning, and will be the means eventually of leading the individual to its greatest accomplishments.

Two Health Foundations through the Nervous System. — These as listed on page 22 are *strong nerves* and an *hygienic disposition*. The first has reference to the nervous system in its relation to the body as a whole; the

second refers to the mind, and the mind as it affects the body and determines our conduct. Both are of the greatest importance.

Summary. — On account of its delicate nature, the nervous system is apt to be injured in the ordinary process of living. Strain and overwork, drugs present in things of everyday use, and cruel ways that people have of treating each other, all can harm the nervous structures and waste the nervous energy. Protection of the nervous system from the different sources of injury requires much care and forethought and the development of certain attitudes and habits of mind that, together, are called the hygienic disposition. The nervous systems of children should receive much consideration from adults. Especially should they be protected from habit-forming drugs, such as alcohol and the nicotine of tobacco.

Exercises. — 1. In what respects is the hygiene of the nervous system the hygiene of the entire body?

2. Name several things that injure the nerves and waste the nervous energy.

3. What bodily conditions are especially harmful?

4. How does a good disposition benefit the nervous system? The health in general?

5. Discuss the hygienic disposition.

6. How does physical exercise benefit the nervous system? How does regular work improve it?

7. State the need for sleep. Give suggestions for getting sound sleep.

8. What is the unanswerable argument for preventing the use of tobacco by the young? How does adult usage complicate the problem?

9. What conditions sometimes present in the schoolroom waste the nervous energy of pupils? What conditions will save it?

10. What is meant by living on a high plane? What are the advantages?

CHAPTER XXVII

PRODUCTION OF SENSATIONS

Our study of the nervous system has shown that impulses arising at the surface of the body are able, through connecting neurons, to bring about various activities. Moving along definite pathways, they induce motion in the muscles, and in the glands the secretion of liquids. It is now our purpose to consider the effect produced by afferent impulses upon the brain and, through the brain, upon the mind.[1] This effect is manifested in a variety of similar forms, known as

The Sensations. — Sensations constitute the lowest forms of mental activity. Roughly speaking, they are the states of mind experienced as the *direct* result of impulses reaching the brain. In a sense, just as impulses passing to the muscles cause motion, impulses passing to the brain cause sensations. The feeling which results from the hand's touching a table is a sensation and so also is the pain which is caused by an injury to the body. The mental action in each case is due to impulses passing to the brain. Care must be exercised by the beginner, however, not to confuse sensations with the nervous impulses, on the one hand, or with *secondary* mental effects, such as emotion or imagination, on the other. Sensations are properly regarded as the first conscious effects of the afferent impulses and as the *beginning stage* in the series of mental processes that may take place on account of them.

[1] The term "mind" is used in this and preceding chapters in its popular, not technical, sense.

In some way, not understood, the mind associates the sensation with the part of the body from which the impulses come. Pain, for example, is not felt at the brain where the sensation is produced, but at the place where the injury occurs. This association, by the mind, of the sensations with different parts of the body, is known as "localizing the sensation."

Sensation Stimuli. — While the sensations are dependent upon the afferent impulses, the afferent impulses are in turn dependent upon causes outside of the nervous system. If these are removed, the sensations cease and they do not start up again unless the exciting influences are again applied. Any agency, such as heat or pressure, which, by acting on the neurons of the body, is able to produce a sensation, may be called a *sensation stimulus*. It has perhaps already been observed that the stimuli that lead to voluntary action, as well as those that produce reflex action of the muscles, cause sensations at the same time. From this we may conclude that sensation stimuli are the same in character as those that excite motion. On the other hand, it should be noted that sensations are constantly resulting from stimuli that are of too mild a nature to cause reflex movements.

Classes of Sensations. — Perhaps as many as twenty distinct sensations, such as pain, hunger, touch, etc., are recognized. If these are studied with reference to their origin, it will be seen that some of them result from the action of definite forms of stimuli upon the neurons terminating in sense organs; while the others, as a rule, arise from the action of indefinite stimuli upon neurons in parts of the body that do not possess sense organs. The members of the first class — and these include the sensations of touch, temperature, taste, smell, hearing, and sight — are

known as the *special* sensations. The others, including the sensations of pain, hunger, thirst, nausea, fatigue, comfort, discomfort, and those of disease, are known as *organic*, or general, sensations. These two classes of sensations differ in their purpose in the body as well as in the manner of their origin.

Purposes of Sensations. — Any given sensation is related to the stimulus which excites it as an *effect* to a *cause*. It starts up or stops, increases in intensity or diminishes, according to the action of the exciting stimulus. As the stimuli are outside of the nervous system, and in the majority of cases outside of the body, the sensations indicate to the mind what is taking place either in the body itself or in its surroundings. They supply, in other words, the means through which the mind acquires information. By means of the special sensations, a knowledge of the physical surroundings of the body is gained, and through the organic sensations the needs of the body and the state of the various organs are indicated. In general, sensations are made to serve two great purposes in the body, as follows:

1. They provide the necessary conditions for intelligent and purposeful action on the part of the body.

2. They supply the basis for the higher mental activities, as perception, memory, thought, imagination, and emotion.

Intelligent action is impossible without a knowledge both of the bodily organs and of the body's surroundings. Protection and the regulation of the work of an organ necessitate a knowledge of its condition, while the adapting and adjusting of the body to its surroundings require a knowledge of what those surroundings are. The dependence of all the higher forms of mental activity upon sensations is recognized by psychologists and is easily

demonstrated by a study of the manner in which we acquire knowledge. "Without sensation there can be no thought."

Steps in the Production of Sensations. — The steps in the production of sensations are not essentially different from those in the production of reflex action. First of all, external stimuli act upon the fiber terminations in the sense organs, or elsewhere, starting impulses in the neurons. These pass into the central nervous system and there excite neurons which in turn discharge impulses into the cerebrum. The result is to arouse an activity of the mind — a sensation. The steps in the production of any *special* sensation naturally involve the following parts:

1. A sense organ where the terminations of the neurons are acted upon by the stimulus.

2. A chain of neurons which connect the sense organ with the brain.

3. The part of the cerebrum which produces the sensation. (Fig. 137.)

Sense Organs. — The sense organs are not parts of the afferent neurons, but are structures of various kinds, in which the neurons terminate. Their function is to enable the sensation stimuli to start the impulses. By directing, concentrating, or controlling the stimuli, the sense organs enable them to act to the best advantage upon the neurons. When it is recognized that such widely different forces as light waves, sound waves, heat, pressure, and odors are enabled by them to stimulate neurons, the importance of these organs becomes apparent. As would naturally be inferred, the construction of any sense organ has particular reference to the nature of the stimulus which it is to receive. This is most apparent in the sense organs of sight and hearing.

Simple Forms of Sense Organs. — The simplest form of a sense organ (if such it may be called) is one found among the various tissues. It consists of the terminal branches of nerve fibers which spread over a small area of cells, as a network or plexus. Such endings are numerous in the skin and muscles.

Next in order of complexity are the so-called *end-bulbs*. These consist of rounded, or elongated, connective tissue capsules, within which the nerve fibers terminate. On the inside the fibers lose their sheaths and divide into branches, which wind through the capsule. End-bulbs are abundant in the lining membrane of the eye, and are found also in the skin of the lips and in the tissues around the joints.

FIG. 139. — **A touch corpuscle** highly magnified. (See text.)

Slightly more complex than the end-bulbs are the *touch corpuscles*. These are elongated bulb-like bodies, having a length of about one three-hundredth of an inch, and occupying the papillæ of the skin (Fig. 139). They are composed mainly of connective tissue. Each corpuscle receives the termination of one or more nerve fibers. These, on entering, lose the medullary sheath and separate into a number of branches that penetrate the corpuscle in different directions.

The largest of the simple forms of sense organs are bodies visible to the naked eye and called, from their discoverer Pacini, the *Pacinian corpuscles*. They lie along the course of nerves in many parts of the body, and have the general form of grains of wheat. (See Practical Work.) The Pacinian corpuscles are composed of connective tissue

arranged in separate layers around a narrow central cavity called the core (Fig. 140). Within the core is the termination of a large nerve fiber. These corpuscles are found in the connective tissue beneath the skin, along tendons, around joints, and among the organs of the abdominal cavity.

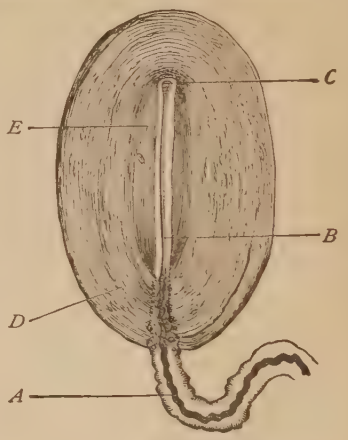

FIG. 140.—**Pacinian corpuscle,** magnified. *A.* Medullated nerve fiber. *B.* Axis cylinder terminating in small bulb at *C*. *D.* Concentric layers of connective tissue. *E.* Inner bulb.

The simple forms of sense organs have a more or less general distribution over the body, and are concerned in the production of at least three special sensations. These are *touch*, *temperature*, and the *muscular sensation.*

Touch, or feeling, is perhaps the simplest of the sensations. The sense organs employed are the touch corpuscles, and the external stimulus is some form of pressure or impact. Pressure applied to the skin, by acting on the fiber terminations in the corpuscles, starts the impulses that give rise to the sensation. The touch corpuscles render the fiber terminations so sensitive that the slightest pressure is able to arouse sensations of touch. It is found that *a change of pressure*, rather than pressure that is constant, is the active stimulus. That all parts of the skin are not equally sensitive to pressure, and that the mind does not interpret equally well the sensations from different parts, are facts easily demonstrated by experiment (See Practical Work.)

The Temperature Sensation. — Temperature sensations,

like those of touch, are limited almost entirely to the skin. They are of two kinds, and are designated as *heat* sensations and as *cold* sensations. Whether the sense organs for temperature are different from those of touch is not known. It is known, however, that the same corpuscles do not respond alike to heat, cold, and pressure.

A Change of Temperature, rather than any specific degree of heat or cold, is the active temperature stimulus. The sensation of warmth is obtained when the temperature of the skin is being raised, and of cold when it is being lowered. This explains why in going into a hallway from a heated room one receives a sensation of cold, while in coming into the same hallway from the outside air he receives a sensation of warmth. It is for the same reason that we are able to distinguish only the relative, not the actual, temperature of bodies.

Muscular Sensations. — These are sensations produced by impulses arising at the muscles. Such impulses originate at the fiber terminations which are found in both the muscles and their tendons. By muscular sensations one is conscious of the location of a contracting muscle and of the degree of its tension. They also make it possible to judge of the weight of objects.

The Sensation of Taste. — The sense organs of taste are found chiefly in the mucous membrane covering the upper surface of the tongue. Scattered over this surface are a number of rounded elevations, or large papillæ (A, Fig. 141). Toward the back of the tongue two rows of these, larger than the others, converge to meet at an angle, where is located a papilla of exceptional size. Surrounding each papilla is a narrow depression, within which are found the sense organs of taste (B, Fig. 141). These are called, from their shape, *taste buds*, and each bud contains a central

cavity which communicates with the surface by a small opening — *the gustatory pore.* Within this cavity are many slender, spindle-shaped cells which terminate in hair-like projections at the end nearest the pore, but in short fibers at the other end. Nerve fibers enter at the inner ends of the buds and spread out between the cells (*C*, Fig. 141).

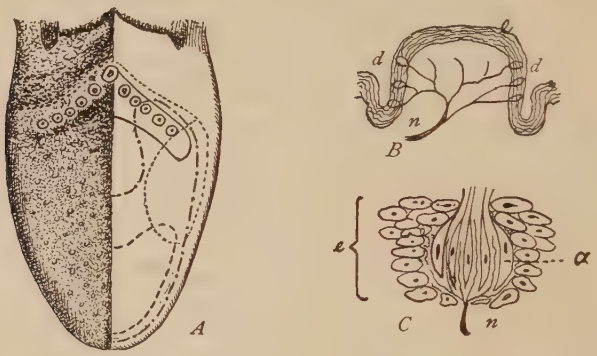

FIG. 141. — **Sense organs of taste.** *A.* Map of upper surface of tongue, showing on the left the different kinds of papillæ, and on the right the areas of taste (after Hall). Area sensitive to bitter (———); to acid (. . . . .); to salt (— · — · — · —); to sweet (— — — — — —). *B.* Section through a papilla. *n.* Small nerve connecting with taste buds at *d*. *e.* Epithelium. *C.* Single taste bud magnified. *n.* Nerve, the fibers of which terminate between the spindle-shaped cells *a*. *e.* Epithelial cells.

These fibers pass to the brain as parts of two pairs of nerves — those from the front of the tongue joining the trigeminal nerve, and those from the back of the tongue, the glossopharyngeal nerve.

The gustatory, or *taste stimulus*, is some chemical or physical condition of substances which is manifested only when they are in a liquid state. For this reason *only liquid substances can be tasted.* Solids to be tasted must first be dissolved.

The different taste sensations are described as bitter, sweet, sour, and saline, and in the order named are recognized as the tastes of quinine, sugar, vinegar, and salt. As to how these different tastes are produced, little is known. Flavors such as vanilla and lemon, and the flavors of meats and fruits, are really smelled and not tasted. Taste serves two main purposes: it is an aid in the selection of food and it is a means of stimulating the digestive glands.

The Sensation of Smell. — The sense organs of smell are found in the mucous membrane lining the upper divisions of the nasal cavities. Here are found two kinds of

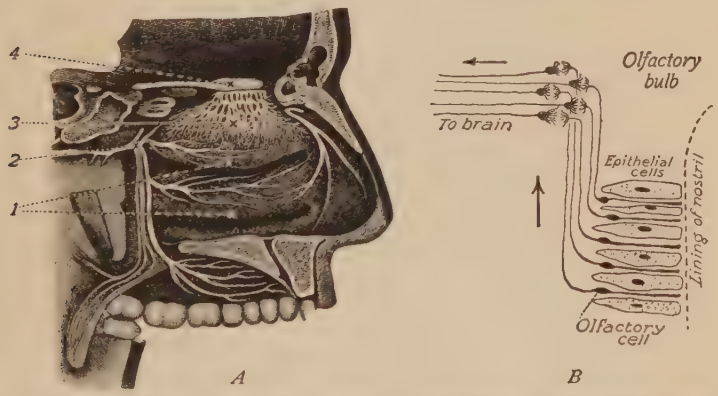

FIG. 142. — **Sense organ of smell.** *A*. Distribution of nerves in outer wall of nasal cavity. 1. Turbinated bones. 2. Branch of fifth pair of nerves. 3. Branches of olfactory nerve. 4. Olfactory bulb. *B*. Diagram showing connection of neurons concerned in smell.

cells in great abundance — column-shaped epithelial cells and the cells which are recognized as the sense organs of smell. These olfactory cells are spindle-shaped, having at one end a slender, thread-like projection which reaches the surface, and at the other end a fiber which joins an olfactory nerve (B, Fig. 142). In fact, the olfactory cells

resemble closely the cell-bodies of neurons, and are thought to be such. The divisions of the olfactory nerve pass through many small openings in the ethmoid bone to connect with the olfactory bulbs, which in turn connect with the cerebrum (A, Fig. 142).

The Olfactory Stimulus. — Only substances in the gaseous state can be smelled. From this it is inferred that the stimulus is supplied by gas particles. Solids and liquids are smelled because of the gas particles which separate from them. The substance which is smelled must be kept moving through the nostrils and made to come in direct contact with the olfactory cells. There is practically no limit to the number of distinct odors that may be recognized.

Value of Smell. — Although the sense of smell is not so acute in man as in some of the lower animals, it is, nevertheless, a most important and useful gift. It is the only sense that responds to matter in the gaseous state, and is, for this reason, the only natural means of detecting harmful constituents of the atmosphere. In this connection it has been likened to a sentinel standing guard over the air passages. Many gases are, however, without odor, and for this reason cannot be detected by the nostrils. It is of especial importance that gases which are likely to become mixed with the air supply to the body have odor, even though the odor be disagreeable. The bad odors of illuminating gas and of various compounds of the chemical laboratory, since they serve as danger signals to put one exposed to them on his guard, are of great protective value.

Sight and Hearing. — The sense organs of sight and hearing are highly complicated structures, and will be considered in the chapters following.

Summary. — Sensations are certain activities of the mind that result from excitations within the body or at its

surface. These cause the neurons to discharge impulses which on reaching the cerebrum cause the sensations. Sensations are necessary for intelligent and purposeful action and for acquiring all kinds of knowledge. To enable the stimuli to act to the best advantage in starting the impulses, special devices, called sense organs, are employed. These receive the terminations of the neurons, and by their special structure enable the most delicate stimuli to start impulses. The simpler forms of sense organs are those of touch, temperature, taste, and smell.

Exercises. — 1. Compare sensations and reflex actions with reference to their nature and cause. Give steps in the production of each.

2. Give examples of sensation stimuli. State the purpose of sense organs.

3. How do general sensations differ from special sensations?

4. Of what value is pain in the protection of the body?

5. Show that sensations lead to the higher forms of mental activity, such as emotion and imagination.

6. Of what value to the body is the "localizing of the sensation"?

7. What kinds of sense organs are found in the skin? State the purpose of each.

8. Through what sense avenues is one made aware of solids, of liquids, and of gases?

9. Of what special protective value is the sense of smell?

PRACTICAL WORK

To demonstrate the Pacinian Corpuscles. — Spread out the mesentery from the intestine of a cat and hold it between the eye and the light. Pacinian corpuscles will appear as small translucent bodies having the general form of grains of wheat. Secure a portion of the mesentery over a circular opening in a thin piece of cork and examine it with a microscope of low power. Follow the course of the nerve fiber to the nerve from which it branches.

To show Relative Sensitiveness of Different Parts of the Skin. — Holding a bristle between the fingers, bring the end in contact with the skin, noting the amount of pressure necessary to cause a sensation of

touch. Test the lips, tongue, tips of fingers, and palm and back of hand, trying different sizes of bristles. Has the degree of sensitiveness any relation to the thickness of the cuticle?

To show Perceptive Differences of Different Portions of the Skin. — Place the points of a pair of dividers on the back of the hand of one who looks in the opposite direction. Is one point felt or two? Repeat several times, changing the distance between the points until it is fully determined how near the two points must be placed in order to be felt as one. In like manner test other parts of the body, as the tips of the fingers and the back of the neck. Compare results obtained at different places.

To locate Warm and Cold Sensation Spots. — Slowly and evenly draw a blunt-pointed piece of metal over the back of the neck. If it be of the same temperature as the skin, only touch sensations will be experienced. If it be a little colder (the temperature of the room) sensations of cold will be felt at certain spots. If slightly warmer than the body, heat sensation spots will be found on other parts of the skin. If the heat and cold sensation spots be marked and tested from day to day they will be found to remain constant as to position. Inference.

CHAPTER XXVIII

THE LARYNX AND THE EAR

MAN is a social being. His inclinations are not to live alone, but to be a part of that great human organization known as society. For men to work together, to be mutually helpful one to another, requires the ability to exchange ideas and this in turn requires some means of communication.[1] One means of communication is found in certain movements of the atmosphere, known as *sound waves*. In the exchange of ideas by this means there are employed two of the most interesting divisions of the body — the larynx and the ear. The first is an instrument for the production of sound waves; the second is the sense organ which enables the sound waves to act as stimuli to the nervous system.

Nature of Sound Waves. — If some sonorous body, as a bell, be struck, it is given a quivering, or vibratory, motion. This is not confined to the bell, but is imparted to the air and other substances with which the bell comes in contact. These take up the movements and pass them to objects more remote, and they in turn give them to others, until a very considerable distance is reached. Such progressive vibrations are known as waves, and, since they act as stimuli to the organs of hearing, they are called *sound waves*. Sound waves *always originate in vibrating bodies*.[2]

[1] The problem of social adjustment is but a phase of the general problem of establishing proper relations between the body and its surroundings.

[2] A vibrating body is one having a to-and-fro movement, like that of a clock pendulum or the string of a violin on sounding. Bodies to give out sound waves

They are transmitted chiefly *by the air*, which, because of its lightness, elasticity, and abundance, readily takes up the vibrations and spreads them in all directions (Fig. 143).

While these vibratory movements of the atmosphere are correctly classified as waves, they bear little resemblance to the waves on water. Instead of being made of crests and troughs, as are the water waves,

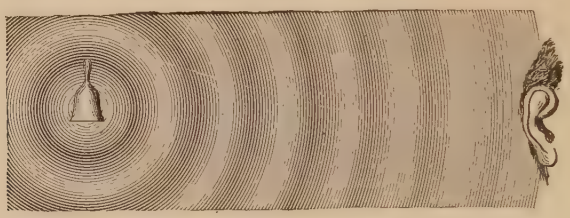

FIG. 143.— **Diagram illustrating the spreading of sound waves through air.**

the sound waves consist of alternating successions of slightly condensed and rarefied layers of air. Then, while the general movement of the water waves is that of ever widening circles *over a surface*, the sound waves spread as enlarging spherical shells *through* the air. In sound waves, as in all other waves, however, it is only the form of the wave that moves forward. The individual particles of air that make up the wave simply vibrate back and forth.

How Sound Waves act as Stimuli. — Any sound wave represents a small but definite amount of energy, this being a part of the original force that acted on the vibrating body to set it in motion. The hammer, for instance, in striking a bell imparts to it a measurable quantity of energy, which the bell in turn imparts to the air. This energy is in the sound waves and is communicated to the

must vibrate rapidly, making not less than sixteen vibrations per second. The upper limit of hearing being about 40,000 vibrations per second, certain bodies may even vibrate too rapidly to be heard.

bodies against which they strike.[1] Though the force exerted by most sound waves is, indeed, very slight, it is sufficient to enable them to act as stimuli to the nervous system.

How Sounds Differ. — Three distinct effects are produced by sound waves upon the nerves of hearing, and through them upon the mind. These are known as *pitch*, *intensity*, and *quality*, and they are dependent upon the vibrations of the sound-producing bodies.

Pitch, which has reference to the height, or degree of sharpness, of tones, is determined by the rapidity of the vibrations of the vibrating body. The more rapid the vibrations, the higher the pitch, the number of vibrations doubling for each musical interval known as the octave.

Intensity is the energy, or force, of the sound waves. This is recognized by the strength of the sensation and is expressed by the term *loudness*. Intensity is governed mainly by the width of the vibrations of the vibrating body, and the width depends upon the force applied to the body to make it vibrate.

Quality is that peculiarity of sound that enables tones from different instruments to sound differently, although they may have the same pitch and intensity. Quality depends upon the fact that most tones are complex in nature and result from the blending together of simple tones of different pitch.

Reënforcement of Sound Waves. — The sound vibrations from small bodies are not infrequently reënforced by surrounding conditions so that their outgoing waves reach farther and are more effective than waves from larger bodies. This is true of the sound waves produced by most musical instruments and also those produced by the human larynx. Such reënforcement is effected in two general ways — by sounding boards and by inclosed columns of air. Stringed instruments — violin, guitar, piano, etc. — employ sounding boards, while wind instruments, as the flute, pipe organ, and the various kinds of horns, employ air columns for reënforcing their vibrations. In the use of the sounding board, the vibrations are communicated to a larger surface, and in the use of the air column the vibrations are communicated to the inclosed air. (See Practical Work.)

[1] Somewhat as the waves on a body of water impart motion to the sticks and weeds along the shore, sound waves are able to cause bodies that are small or that are delicately poised to vibrate.

Value of Sound Waves to the Body. — From a physiological standpoint, the value of sound waves is not easily overestimated. In addition to the use made of them in the communication of ideas, they serve the purpose of protecting the body, and in the sphere of music provide one of the most elevating forms of entertainment. Sounds from different animals, as well as from inanimate objects, may also be the means of supplying needed information. The existence of two kinds of sound instruments in the body — the one for the production, the other for the detection, of sound — is certainly suggestive of the ability of the body to adjust itself to, and to make use of, its physical environment. Both the larynx and the ear are constructed with special reference to the nature and properties of sound waves.

THE LARYNX

The Sound-producing Mechanism of the Body consists of the following parts :

1. Delicately arranged bodies that are easily set in vibration.
2. An arrangement for supplying the necessary force for making these bodies vibrate.
3. Contrivances for modifying the vibrating parts so as to produce changes in pitch and intensity.
4. Parts that reënforce the vibrations.
5. Organs by means of which the sounds are converted into the forms of speech.

The central organ in this complex mechanism is

The Larynx. — The larynx forms a part of the air passages, being a short tube at the upper end of the trachea. Mucous membrane lines the inside of it and muscles cover most of the outer surface. The framework

is made of cartilage. At the top it is partly encircled by a small bone (the hyoid), and its opening into the pharynx is guarded by a flexible lid, called the *epiglottis*. The cartilage in its walls is in eight separate pieces, but the greater portion of the structure is formed of two pieces only. These are known as the *thyroid cartilage* and the *cricoid cartilage* (Fig. 144). Both can be felt in the throat — the thyroid as the projection known as "Adam's apple," and the cricoid as a broad ring just below.

The *thyroid cartilage* consists of two V-shaped pieces, one on either side of the larynx, meeting at their points

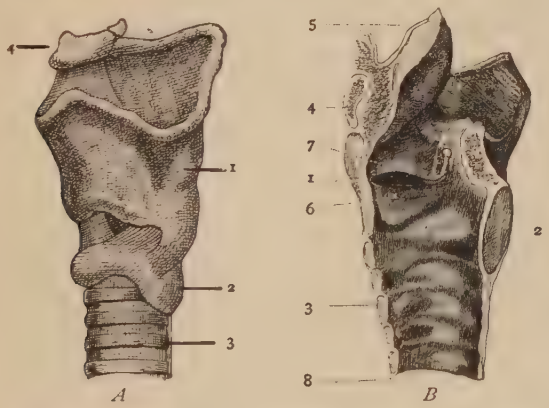

FIG. 144. — **The larynx.** — *A*. Outside view. *B*. Vertical section through larynx, showing inside. 1. Thyroid cartilage. 2. Cricoid cartilage. 3. Trachea. 4. Hyoid bone. 5. Epiglottis. 6. Vocal cord. 7. False vocal cord. 8. Lining of mucous membrane.

in front, and each terminating at the back in an upward and a downward projection. Between the back portions of the thyroid is a space equal to about one third of the circumference of the larynx. This is occupied by the greater portion of the *cricoid cartilage*. This cartilage

has the general shape of a signet ring and is so placed that the part corresponding to the signet fits into the thyroid space, while the ring portion encircles the larynx just below the thyroid. Muscles and connective tissue pass from the thyroid to the cricoid cartilage at all places, save one on each side, where the downward projections of the thyroid form hinge joints with the cricoid. These joints permit of motion of either cartilage upon the other.

At the summit of the cricoid cartilage, on each side, is a small piece of triangular shape, called the *arytenoid cartilage*. Each arytenoid is movable on the cricoid and is connected with one end of a vocal cord.

The Vocal Cords are formed by two narrow strips of tissue which, connecting with the thyroid cartilage in front and the arytenoid cartilages behind, lie in folds of the mucous membrane. They have the general appearance of ridge-like projections from the sides of the larynx, but

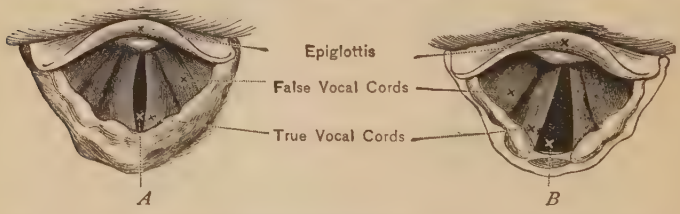

FIG. 145. — **Vocal cords** as seen from above. *A*. In producing sound. *B*. During quiet breathing.

at their edges they are sharp and smooth. The open space between the cords is called the *glottis*. When sound is not being produced, the glottis is open and has a triangular form, due to the spreading apart of the arytenoid cartilages and the attached cords. But when sound is being produced, the glottis is almost completely closed by the cords. Above the vocal cords, and resembling them in appear-

ance, are two other folds of membrane, called the *false vocal cords* (B, Fig. 144). The false cords do not produce sound, but they aid in the closing of the glottis.

How the Voice is Produced. — The voice is produced through the vibrations of the vocal cords. A special set of muscles draws the arytenoid cartilages toward each other, thereby bringing their edges very near and parallel to each other in the passage. At the same time other muscles act on the thyroid and cricoid cartilages to separate them at the top and give the cords the necessary tension. With the glottis now almost closed, blasts of air from the lungs strike the sharp edges of the cords and set them in vibration (Fig. 145). The vocal cords do not vibrate as strings, like the strings of a violin, but somewhat as reeds, similar to the reeds of a French harp or reed organ.

The location of the vocal cords in the air passages enables the lungs and the muscles of respiration to aid in the production of the voice. It is their function to supply the necessary force for setting the cords in vibration. The upper air passages (mouth, nostrils, and pharynx) supply resonance chambers for reënforcing the vibrations from the vocal cords, thereby greatly increasing their intensity. In ordinary breathing the vocal cords are in a relaxed condition against the sides of the larynx and are not acted upon by the air as it enters or leaves the lungs.

Pitch and Intensity of the Voice. — Changes in the pitch of the voice are caused mainly by variations in the tension of the cords, due to the movements of the thyroid and cricoid cartilages upon each other.[1] In the production of tones of very high pitch, the vibrating portions of the cords

[1] Some idea of how the movements of the cartilages change the tension of the cords may be obtained by holding the fingers on the larynx, between the thyroid and cricoid cartilages, and making tones first of low and then of high pitch. For

are thought to be actually shortened by their margins being drawn into contact at the back. This raises the pitch in the same manner as does the shortening of the vibrating portion of a violin string.

The *intensity*, or loudness, of the voice is governed by the force with which the air is expelled from the lungs. The vibrations of the cords, however, are greatly reënforced by the peculiar structure of the upper air passages, as stated above.

Production of Speech. — The sounds that form our speech or language are produced by modifying the vibrations from the vocal cords. This is accomplished by "mouthing" the sounds from the larynx. The distinct sounds, or words, are usually complex in nature, being made up of two or more elementary sounds. These are classed either as *vowels* or *consonants* and are represented by the different letters of the alphabet. The vowel sounds are made with the mouth open and are more nearly the pure vibrations of the vocal cords. The consonants are modifications of the vocal cord vibrations produced by the tongue, teeth, lips, and throat.

Words and their Significance. — In the development of language certain ideas have become associated with certain sounds so that the hearing of these sounds suggests the ideas. Our words, therefore, consist of so many sound signals, each capable of arousing a definite idea in the mind. To talk is to express ideas through these signals, and to listen is to assume an attitude of mind such that the signals may be interpreted. In learning a language, both the sounds of the words and their associated ideas are

the high tones the cartilages are pulled together in front, and for the low tones they separate. As they pull together in front, they of course separate behind and above, where the cords are attached.

mastered, this being necessary to their practical use in exchanging ideas. From spoken language man has advanced to written language, so that the sight of the written or printed word also arouses in the mind the associated idea.

THE EAR

The Ear is the sense organ which enables sound waves to so act upon afferent neurons as to excite impulses in them. The effect upon the mind which these impulses produce is known as the *sensation of hearing*. In the performance of its function the ear receives and transmits sound waves and also concentrates them upon a suitable exposure of nerve cells. It includes three parts — the *external ear*, the *middle ear*, and the *internal ear*.

External Ear. — The external ear consists of the part on the outside of the head called the *pinna*, or auricle, and the tube leading into the middle ear, called the *auditory canal* (Fig. 146). The pinna by its peculiar shape aids to some extent the entrance of sound waves into the auditory canal.[1] It consists chiefly of cartilage. The auditory canal is a little more than an inch in length and one fourth of an inch in diameter, and is closed at its inner end by a thin, but important membrane, called

The Membrana Tympani. — This membrane consists of three thin layers. The outer layer is continuous with the lining of the auditory canal; the inner is a part of the lining of the middle ear; and the middle is a fine layer of connective tissue. Being thin and delicately poised, the membrana tympani is easily made to vibrate by the sound

[1] It is only the central portion of the pinna that aids the entrance of sound into the auditory canal. If by accident the outer portion of the pinna is removed, there is no impairment of the hearing.

waves that enter the auditory canal. In this way it serves as a receiver of sound waves from the air. It also protects

The Middle Ear. — The middle ear, or tympanum,[1] consists of an irregular cavity in the temporal bone which is lined with mucous membrane and filled with air. It is

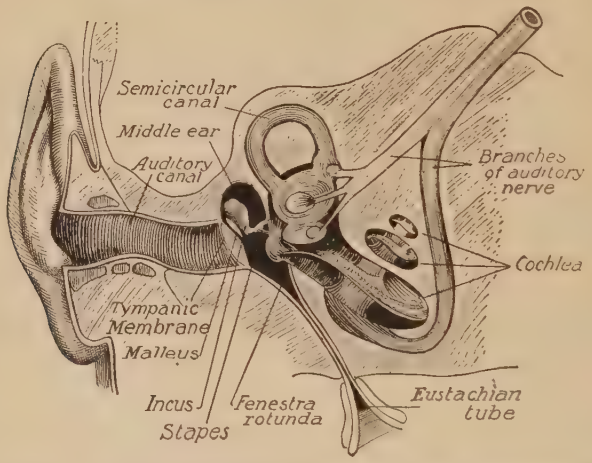

Fig. 146. — Diagram of section through the ear, showing relations of its various parts. (See text.)

connected with the pharynx by a slender canal called the *Eustachian tube*. Extending across the middle ear and connecting with the membrana tympani on one side, and with a membrane closing a small passage to the internal ear on the other, is a tiny bridge formed of three small bones. These bones, named in their order from the membrana tympani, are the *malleus*, the *incus*, and the *stapes* (Fig. 146). Where the malleus joins the membrane is a small muscle whose contraction has the effect of tighten-

[1] The middle ear is also called the *ear drum*, and, by the same system of naming, the membrana tympani is referred to as the *drum membrane*.

ing the membrane. The Eustachian tube admits air freely to the middle ear, providing in this way for an equality of atmospheric pressure on the two sides of the drum membrane. The bridge of bones and the air in the middle ear receive vibrations from the membrana tympani and communicate them to the membrane of the internal ear.

Purposes of the Middle Ear. — The middle ear serves two important purposes. In the first place, it makes it possible for sound waves to set the membrana tympani in vibration. This membrane could not be made to vibrate by the more delicate of the sound waves if it were stretched over a bone, or over some of the softer tissues, or over a liquid. Its vibration is made possible by the presence of air on *both* sides, and this condition is supplied, on the inner side, by the middle ear. The Eustachian tube, by providing for an *equality* of pressure on the two sides of the membrane, also aids in this purpose.

In the second place, the middle ear provides a means for *concentrating the force of the sound waves* as they pass from the membrana tympani to the internal ear. This concentration is effected in the following manner:

1. The bridge of bones, being pivoted at one point to the walls of the middle ear, forms a lever in which the malleus is the long arm, and the incus and stapes the short arm, their ratio being about that of three to two. This causes the incus to move through a shorter distance, but with greater force than the end of the malleus.

2. The area of the membrana tympani is about twenty times as great as the membrane of the internal ear which is acted upon by the stapes. The force from the larger surface is, therefore, concentrated by the bridge of bones upon the smaller surface. By the combination of these two devices, the waves striking upon the membrane of the internal ear are rendered some thirty times more effective than are the same waves entering the auditory canal.

The Internal Ear, or labyrinth, occupies a series of irregular channels in the petrous process of the temporal bone.[1] It is very complicated in structure, and at the same time is very small. Its greatest length is not more

[1] The inner projection of the temporal bone is known as the petrous process.

than three fourths of an inch and its greatest diameter not more than one half of an inch. It is filled with a liquid which at one place is called the *perilymph*, and at another place the *endolymph*. It is a double organ, being made up of an outer portion which lies next to the bone, and which surrounds an inner portion of the same general form. The outer portion is surrounded by a membrane which serves as periosteum to the bone and, at the same time, holds the liquid belonging to this part, called the perilymph. The inner portion, called the *membranous labyrinth*, consists essentially of a closed membranous sac, which is filled with the endolymph. The auditory nerve terminates in this portion of the internal ear. Three distinct divisions of the labyrinth have been made out, known as the *vestibule*, the *semicircular canals*, and the *cochlea* (Fig. 147).

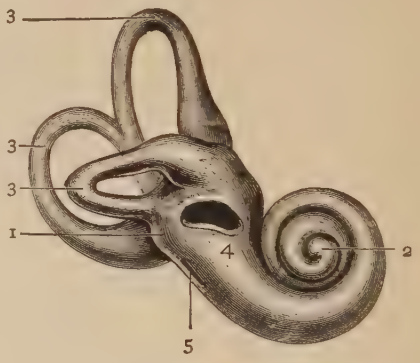

FIG. 147.—**General form of internal ear.** The illustration represents the structures of the internal ear surrounded by a thin layer of bone. 1. Vestibule. 2. Cochlea. 3. Semicircular canals. 4. Fenestra ovalis. 5. Fenestra rotunda.

The Vestibule forms the central portion of the internal ear and is somewhat oval in shape. It is in communication with the middle ear through a small opening in the bone, called the *fenestra ovalis*, at which place it is separated from the middle ear only by a thin membrane. Sound waves enter the liquids of the internal ear at this point, the foot of the stapes being attached to the membrane.

Six other openings lead off from the vestibule at different places. One of these enters the cochlea. The other five open into

The Semicircular Canals. — These canals, three in number, pass through the bone in three different planes. One extends in a horizontal direction and the other two vertically, but each plane is at right angles to the other two. Both ends of each canal connect with the vestibule, though two of them join by a common opening. The inner membranous labyrinth is continuous through each canal, and is held in position by small strips of connective tissue.

The purpose of the semicircular canals is not understood. It is known, however, that they are not used in hearing. On the other hand, there is evidence to the effect that they act as equilibrium sense organs, exciting sensations necessary for balancing the body. Their removal or injury, while having no effect upon the hearing, does interfere with the ability to keep the body in an upright position.

The Cochlea is the part of the internal ear directly concerned in hearing. It consists of a coiled tube which makes two and one half turns around a central axis and bears a close resemblance to a snail shell (Figs. 146 and 147). It differs in plan from a snail shell, however, in that its interior space is divided into three distinct channels, or canals. These lie side by side and are named, from their relations to other parts, the *scala vestibula*, the *scala tympani*, and the *scala media*. In the middle one of these canals, the scala media, the fibers of the auditory nerve terminate (Fig. 148).

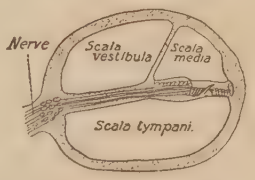

FIG. 148. — **Diagram** showing the divisions of cochlear canal.

How We Hear. — The sound waves which originate in vibrating bodies are transmitted by the air to the external ear. Passing through the auditory canal, the waves strike against the membrana tympani, setting it into vibration. By the bridge of bones and the air within the middle ear the vibrations are carried to and concentrated upon the liquid in the internal ear (Fig. 149). From here the vibrations pass through the channels of the cochlea and set into vibration certain structures found in the scala media. This serves as a stimulus to the fibers of the auditory nerve, causing them to transmit impulses which, on reaching the auditory area of the cerebrum (Fig. 137), produce the sensation of hearing.

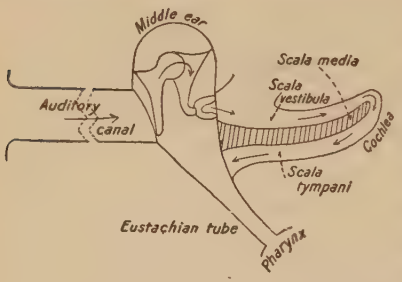

FIG. 149. — **Diagram** illustrating passage of sound waves through the ear.

HYGIENE OF THE EAR

The delicate structures in the middle and internal ears are subject to injuries from two directions — from *without* through the auditory canals and from *within* through the eustachian tubes. We must give needed protection from both directions.

To Protect the Outer Canals. — We should protect them from severe slaps on the side of the head as these may, by driving in the air, break the drum membrane. Hard substances, such as wooden splints, hairpins, or nutpicks, must not be thrust into the canal as these irritate the lining and may puncture the drum. Special care also needs to

be taken in washing the ears in that the cleansing process is not carried into the canal farther than it should be. A soft cloth wet in warm water and laid over a finger will penetrate as far as we can safely go and remove all the wax that should be removed.[1]

Excess of Earwax. — It frequently happens that wax collects in the auditory canal and closes up the passageway (Fig. 150) or gets on the drum membrane to the extent of causing deafness. This may come about without pain and so gradually that one does not think to secure medical aid. The wax, however, is easily removed by the physician and the hearing restored. Its accumulation is prevented by avoiding irritation to the lining of the canal, as suggested above, and by not sleeping in a draft.

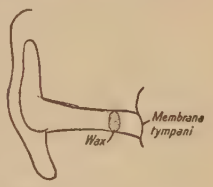

FIG. 150. — **Diagram** showing how wax may plug the auditory canal and cause deafness.

Foreign Objects in the Auditory Canal. — Grains of wheat and other small objects very frequently get into the outer canals. The main precaution when this happens is to have the object removed by a physician unless we can get it to drop out by holding the head to one side and jarring the head or shaking the ear with the fingers. Crude efforts to force objects from the canal have resulted in injury. No harm will result from waiting until the doctor can be seen. Water lodged in the outer canal from being in swimming can usually be jarred out by holding the head to one side and hopping about.

Danger from Within. — The most serious of our ear troubles are the infections of the middle ear and of ad-

[1] The earwax has antiseptic properties and protects the canal from invasions by insects and germs. It has a natural method of discharge which is greatly interfered with by any attempt to scrape it out with hard objects inserted into the canal.

jacent structures.[1] Germs, to cause these, must gain entrance through the eustachian tubes. While all infections of these parts are very serious and require the prompt services of the physician, a more important matter is to keep them from occurring in the first place. This requires proper guarding of the eustachian tubes by the individual.

To Guard the Eustachian Tubes. — There are at least three important ways of doing this, as follows:

1. *By keeping the nose and throat healthy.* Germs to enter the eustachian tubes must first find a lodging place in the nose or the throat. If these places are kept healthy, there is no chance for the germs reaching the middle or internal ears.

2. *By a proper method of blowing the nose.* Forcible blowing has the effect of opening the eustachian tubes and of pushing any fluid that may be near into their mouths. In blowing the nose, the nostrils should be left well open and only a little force used. To blow hard enough to feel the drum membranes push out is to blow too hard. If the nostrils are normal in size, they may safely be blown, one at a time, by closing the opposite nostril with the finger.

3. *By suitable protection for the head at night.* A draft against the side of the head when one is asleep is very apt to congest the linings of the middle ear and the eustachian tubes (p. 76) and to lower their resistance to attacks of germs. Night drafts must be avoided, and those with sensitive ears should provide some special protection for the head, such as a cap made of some light material.

[1] These include ear abscess, running or discharging ear, and mastoid abscess. *Ear abscess* is of the nature of a boil in the middle ear and *running ear* is a frequent sequence of this infection. Instead of healing, the abscess becomes a running sore. *Mastoid abscess* is an infection in the mastoid division of the temporal bone — the hard protrusion just back of the ear.

Harm from Snuffing Liquids. — The snuffing of liquids, such as salt water, up the nose is often the worst possible thing for the ears. The liquid washes germs from the nose linings back into the pharynx and over the entrances to the tubes. If this is followed, as is often the case, by forcible blowing of the nose, this material is very apt to be pushed into the tubes. In carrying out any kind of treatment for the nostrils, one should carefully follow the advice of the physician.

Ear Troubles from Adenoids and Diseased Tonsils. — Those having adenoids and diseased tonsils are very often the victims of ear diseases and of poor hearing. Germs from these places find their way into the eustachian tubes. Prevention is accomplished, of course, through the removal of the adenoids and the tonsils also, if these cannot be kept healthy.

Summary. — Sound waves constitute the external stimuli for the sensation of hearing. They consist of progressive vibratory movements of the air that originate in vibrating bodies. Through the larynx and the ear, sound waves are utilized by the body in different ways, but chiefly as a means of communication. The larynx produces sound waves which are reënforced and modified by the air passages. The ear supplies suitable conditions for the action of sound waves upon nerve cells. Both the ear and the larynx are constructed with special reference to the nature and properties of sound waves, and they illustrate the body's ability to adjust itself to, and to make use of, its physical environment.

Exercises. — 1. For what different purposes are sound waves employed in the body?

2. How do sound waves originate? How are they transmitted? How do they differ from the waves on water?

3. How are sound waves able to act as nerve stimuli?

4. Describe two methods of reënforcing sound waves. Which method is employed in the body?

5. Name all the parts of the body that are directly or indirectly concerned in the production of sound.

6. Describe the larynx.

7. Describe the position and condition of the vocal cords in speaking and in ordinary breathing.

8. How are sounds differing in pitch and intensity produced by the larynx?

9. How is the sound produced by the vocal cords changed into speech?

10. What parts of the ear are concerned in transmitting sound waves?

11. Give the purposes of the middle ear.

12. Trace a sound wave from a bell to the scala media and the impulse that it causes from there to the brain.

13. What harm may result from an excess of earwax? How is relief secured? How is the trouble prevented?

14. State the nature of ear abscess. Of mastoid abscess. Of running ear. How are all avoided?

15. What method of blowing the nose may result in injury to the ear? Explain.

PRACTICAL WORK

To Illustrate the Origin of Sound. — 1. Strike a bell an easy blow and hold some light substance, as a pith ball attached to a thread, against the side, noting the result. 2. Sound a tuning fork by striking it against the table. Test it for vibrations as above, or by letting the vibrating prongs touch the surface of water. 3. Pluck a string of a guitar or violin, and find proof that it is vibrating while giving out sound.

To Show Effects of Sound Waves. — 1. Place two large tuning forks of the same pitch, and mounted on thin boxes for reënforcing their vibrations, near each other on a table. Vibrate one of the forks for a moment and then stop it by means of the hand. Observe that the other fork has been set in vibration. (This experiment does not work with forks of different pitch.) 2. While holding a thin piece of

paper against a comb with the open lips, produce musical tones with the vocal cords. These will set the paper in vibration, producing the so-called " comb music." 3. Examine the disk in a telephone which is set in vibration by the voice. Observe that it is a thin disk and, like the membrane of the ear, has air on both sides of it.

To Show the Reënforcement of Sound. — 1. Vibrate a tuning fork in the air, noting the feebleness of the tone produced. Then hold the stem against a door or the top of a table, noting the difference. 2. Hold a vibrating tuning fork over a tall jar, or bottle, and gradually add water. If the vessel is sufficiently tall, a depth will be reached where the air in the vessel reënforces the sound from the fork. 3. Hold a vibrating fork over the mouth of a small fruit jar, partly covered with a piece of cardboard. By varying the size of the opening, a position will be found where the sound is reënforced. If not successful at first, try bottles and jars of different sizes.

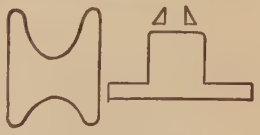

FIG. 151. — **Simple apparatus** for demonstrating the larnyx.

To Show the Plan of the Larynx. — Cut from stiff paper four pieces of different shapes as indicated in Figure 151. (The piece to the right should have a length of about six inches, the others proportionally large.) The largest represents the thyroid cartilage, the next in size the cricoid, and the two smallest the arytenoid cartilages. By means of pins, or threads, connect these with each other according to the description of the larynx on page 363. With this simple model the movements of the different cartilages and their effect upon the vocal cords may be illustrated.

CHAPTER XXIX

THE EYE

The sensation of sight is the chief means of bringing the body into right relations with its surroundings and is our best avenue for the reception of ideas. The sense organs of sight are the eyes; the external stimulus is

Light. — Light, though differing from sound in essential respects,[1] is like sound in consisting of vibratory movements, or waves, and also in the fact that its waves possess energy. They make impressions upon objects. Vision depends in part upon the last-named fact.

The Problem of Seeing. — What we call *seeing* is vastly more than the stimulation of the brain through the action of light upon afferent neurons. It is the *perceiving* of all the different things that make up our surroundings. If one looks toward the clear sky, he receives a *sensation of light*, but sees no object. He may also get a sensation of light with the eyelids closed, if he turn the eyes toward the window or some bright light. But how different when the light from various objects enters the eyes. There is apparently no consciousness of light, but instead a consciousness of the size, form, color, and position of the objects. *Seeing is perceiving objects.* Stimulation by the light waves is only the means toward this end. The chief problem in the study of sight, therefore, is that of deter-

[1] Consult some work on physics.

mining *how light waves enable us to become conscious of objects.*

Image Stimulation. — In order to perceive objects, they must in some way impress themselves upon our nerves and through our nerves upon our minds. This is accomplished through the formation of *images* upon sensitized nervous surfaces in our eyeballs in a manner similar to the formation of images upon screens (Fig. 152) or upon the

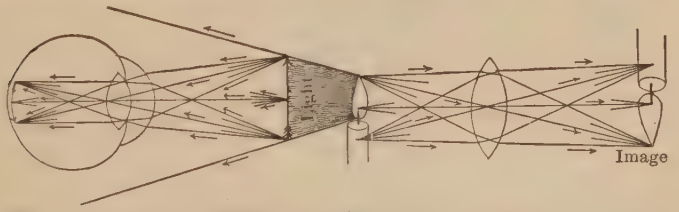

FIG. 152. — **Diagram illustrating formation of images.** On the right the image is formed by a double convex lens; on the left by the lenses of the eye. The candle flame represents a luminous, or light-giving, body; but light passes from the large arrow by reflection. (See text.)

film in a camera. The process is called focusing [1] and is a phase of the general process of refraction as explained in textbooks on physics. Our two eyeballs are devices for forming the images of objects and causing them to fall in a proper manner upon the nervous surfaces. Through the images we receive a form of stimulation that makes us conscious of objects and of our environment in general.

The Eyeball, in shape, is nearly spherical, being about

[1] Focusing means literally the bringing of light to a point, but it is evident in the formation of an image that the light waves are not all brought to a single point. If they were, there would be no image. In Figure 152 the light from the candle comes from a great number of points in the candle flame. The lens, by its peculiar shape, bends the waves coming from any single point so that they are brought to a corresponding point on the screen. Furthermore, the points of focused light are made to occupy the same relative positions on the screen as the points from which they come in the flame. This is why the area of light on the screen has the same form as the candle, or makes an image of it.

an inch in diameter from right to left and nine tenths of an inch both in its vertical diameter and from front to back. It has the appearance of having been formed by the union of two spherical segments of different size. The smaller segment, which forms about one sixth of the whole, is set upon the larger and forms the projecting transparent portion in front. The walls of the eyeballs are made up of three separate layers, or coats — an *outer coat*, a *middle coat*, and an *inner coat* (Fig. 153).

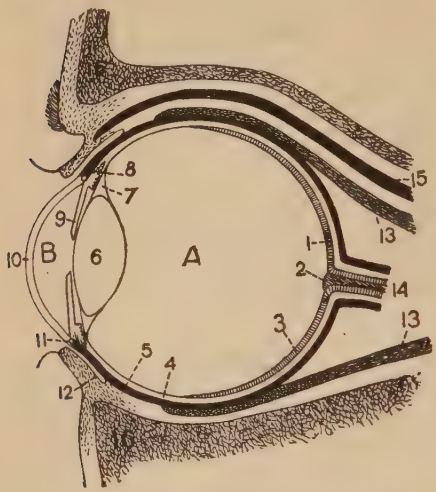

FIG. 153. — **Diagram of the eyeball in position.** 1. Yellow spot. 2. Blind spot. 3. Retina. 4. Choroid coat. 5. Sclerotic coat. 6. Crystalline lens. 7. Suspensory ligament. 8. Ciliary processes and ciliary muscle. 9. Iris containing the pupil. 10. Cornea. 11. Lymph duct. 12. Conjunctiva. 13. Inferior and superior recti muscles. 14. Optic nerve. 15. Elevator muscle of eyelid. 16. Bone. *A*. Posterior chamber containing the vitreous humor. *B*. Anterior chamber containing the aqueous humor.

The Outer Coat surrounds the entire globe of the eye and consists of two parts — the sclerotic coat and the cornea. The *sclerotic coat* covers the greater portion of the larger spherical segment and is recognized in front as "the white of the eye." It is composed mainly of fibrous connective tissue and is dense, opaque, and tough. It preserves the form of the eyeball and protects the portions within. It is pierced at the back by a small opening which admits the

optic nerve, and in front it becomes changed into the peculiar tissue that makes up the cornea.

The *cornea* forms the transparent covering over the lesser spherical segment of the eyeball, shading into the sclerotic coat at its edges. It has a complex structure, consisting in the main of a transparent form of connective tissue. It serves the purpose of admitting light into the eyeball and also acts as a lens.

The Middle Coat consists of three connected portions — the *choroid coat*, the *ciliary processes*, and the *iris*. These surround the larger spherical segment. All three parts are rich in blood vessels, containing the blood supply to the greater portion of the eyeball.

The *choroid coat* lies immediately beneath the sclerotic coat at all places except a small margin toward the front of the eyeball. It is composed chiefly of blood vessels and a delicate form of connective tissue that holds them in place. It contains numerous pigment cells which give it a dark appearance and serve to absorb surplus light. Near where the sclerotic coat joins the cornea, the choroid coat separates from the outer wall and, by folding, forms many slight projections into the interior space. These are known as the *ciliary processes*. The effect of these folds is to collect a large number of capillaries into a small space and to give this part of the eyeball an extra supply of blood. Between the ciliary processes and the sclerotic coat is a small muscle, containing both circular and longitudinal fibers, called the *ciliary muscle*.

The *iris* is a continuation of the choroid coat across the front of the eyeball. It forms a dividing curtain between the two spherical segments and gives the color to the eye. At its center is a circular opening, called the *pupil*, which admits light to the back of the eyeball. By varying the

size of the pupil, the iris is able to regulate the amount of light which passes through and it employs for this purpose two sets of muscular fibers. One set of fibers forms a thin band which encircles the pupil and serves as a sphincter to diminish the opening. Opposing this are radiating fibers which are attached between the inner and outer margins of the iris. By their contraction the size of the opening is increased. Both sets of fibers act reflexively and are stimulated by variations in the light falling upon the retina.

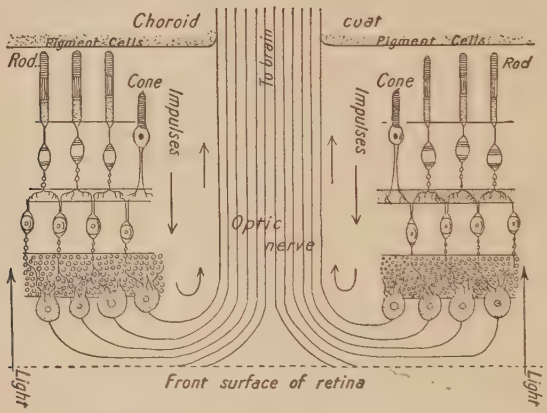

FIG. 154. — **Diagram showing main nervous elements in the retina.** Light waves stimulate the rods and cones at back surface of the retina, starting impulses which excite the ganglion cells at the front surface. Fibers from the ganglion cells pass into the optic nerve.

The Inner Coat, or Retina. — This is a delicate membrane containing the expanded termination of the optic nerve. It rests upon the choroid coat and spreads over about two thirds of the back surface of the eyeball. Although not more than one fiftieth of an inch in thickness, it presents a very complex structure, essentially nervous, and is

made up of several distinct layers. Of chief importance in the outer layer are the cells which are acted upon directly by the light and are named, from their shape, the *rods* and *cones*. In contact with these, but occupying a separate layer, are the ends of small afferent neurons. These in turn communicate with nerve cells in a third layer, known as the ganglion cells, that send their fibers into the optic nerve (Fig. 154).

In the center of the retina is a slight oval depression having a faint yellowish color, and called, on that account, the *yellow spot*. This is the part of the retina which is most sensitive to light. Directly over the place of entrance of the optic nerve is a small area from which the rods and cones are absent and which, therefore, is not sensitive to light. This is called the *blind spot*. (See Practical Work.)

The Crystalline Lens. — Immediately back of the iris and touching it is a transparent, rounded body, called the crystalline lens. This is about one fourth of an inch thick and one third of an inch through its long diameter, and is more curved on the back than on the front surface. It is inclosed in a thin sheath, called the *membranous capsule*, which connects with a divided sheath from the sides of the eyeball, called the *suspensory ligament* (Fig. 153). Both the lens and the capsule are highly elastic.

Chambers and "Humors" of the Eyeball. — The crystalline lens together with the suspensory ligament and the ciliary processes form a partition across the eyeball. This divides the eye space into two separate compartments, which are filled with the so-called "humors" of the eye. The front cavity of the eyeball, which is again divided in part by the iris, is filled with the *aqueous* humor. This is a clear, lymph-like liquid which contains an occa-

sional white corpuscle. It has a feeble motion and is slowly added to and withdrawn from the eye. It is supplied mainly by the blood vessels in the ciliary processes and finds a place of exit through a small lymph duct at the edge of the cornea (Fig. 153).

The back portion of the eyeball is filled with a soft, transparent, jelly-like substance, called the *vitreous* humor. It is in contact with the surface of the retina at the back and with the attachments of the lens in front, being surrounded by a thin covering of its own, called the *hyaloid membrane*. The aqueous and vitreous humors aid in keeping the eyeball in shape and also in focusing.

How we see Objects. — To see an object at least four things must happen:

1. Light must pass from the object into the eye. Objects cannot be seen where there is no light or where, for some reason, it is kept from entering the eye.

2. The light from the object must be focused (made to form an image) on the retina. In forming the image, an area of the retina is stimulated which corresponds to *the form of the object.*

3. Impulses must pass from the retina to the brain, stimulating it to produce the sensations.

4. The sensations must be so interpreted by the mind as to give an impression of the object.

Focusing Power of the Eyeball. — The eyeball is essentially a device for focusing light. All of its transparent portions are directly concerned in this work, and the portions that are not transparent serve to protect and operate these parts and hold them in place. Of chief importance are the crystalline lens and the cornea. Both of these are lenses. The cornea with its inclosed liquid is a plano-convex lens, while the crystalline lens is

double convex.[1] Because of the great difference in density between the air on the outside and the aqueous humor within, the cornea is the more powerful of the two. The crystalline lens, however, performs a special work in focusing which is of great importance. The iris also aids in focusing since it, through the pupil, regulates the amount of light entering the back chamber of the eyeball and causes it to fall in the center of the crystalline lens, the part which focuses most accurately.

Accommodation. — A difficulty in focusing arises from the fact that the degree of divergence of the light waves

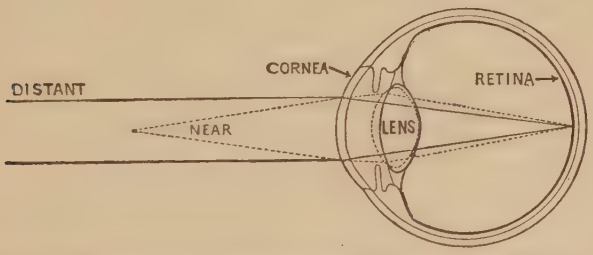

FIG. 155. — **Diagram showing changes in shape of crystalline lens to adapt it to near and distant vision.**

entering the eye from different objects, varies according to their distance. Since the waves from any given point on an object pass out in straight lines in all directions, the waves that enter the eye from distant objects are at a different angle from those that enter from near objects. In reality waves from distant objects are practically parallel, while those from very near objects diverge to a considerable degree. To adjust the eye to different distances requires some change in the focusing parts that corresponds to the differences in the divergence of the light.

[1] Consult some work on physics on the different kinds of lenses and their uses.

This change, called *accommodation*, occurs in the crystalline lens.[1] In the process of accommodation, changes occur in the shape of the crystalline lens, as follows:

1. In looking from a distant to a near object, the lens becomes more convex, *i.e.*, rounder and thicker (Fig. 155). This change is necessary because the greater divergence of the light from the near objects requires a greater converging power on the part of the lens.[2]

2. In looking from near to distant objects, the lens becomes flatter and thinner (Fig. 155). This change is necessary because the less divergent waves from the distant objects require less converging power on the part of the lens.

The method employed in changing the shape of the lens is difficult to determine and different theories have been advanced to account for it. The following, proposed by Helmholtz, is the theory most generally accepted:

The lens is held in place back of the pupil by the suspensory ligament. This is attached at its inner margin to the membranous capsule, and at its outer margin to the sides of the eyeball, and entirely surrounds the lens. It is drawn perfectly tight so that the sides of the eyeball exert a continuous tension, or pull, on the membranous capsule, which, in its turn, exerts pressure on the sides of the lens, tending to flatten it. This arrangement brings the elastic force of the eyeball into opposition to the elastic force of the lens. The ciliary muscle plays between these opposing forces in the following manner:

To thicken the lens, the ciliary muscle contracts, pulling forward the suspensory ligament and releasing its tension on the membranous

[1] With respect to its adjustments the eye does not differ in principle from various other optical instruments, such as the microscope, telescope, photographer's camera, etc., which, in their use, form images of objects. These all require some adjustment of their parts, called focusing, which adapts them to the distance. The eye's method of focusing, however, differs from that of most optical instruments, in that the adjustment is brought about through changes in the curvature of a lens.

[2] The converging power of convex lenses varies as the curvature — the greater the curvature, the greater the converging power.

capsule. This enables the lens to thicken on account of its own elastic force. *To flatten the lens*, the ciliary muscle relaxes, the elastic force of the eyeball resumes its tension on the suspensory ligament, and the membranous capsule resumes its pressure on the sides of the lens. This pressure, overcoming the elastic force of the lens, flattens it.

Movements of the Eyeballs. — In order that the light may enter the eyeballs to the best advantage, they must be moved in various directions. These movements are brought about through the action of six small muscles attached to each eyeball. Four of these, named, from

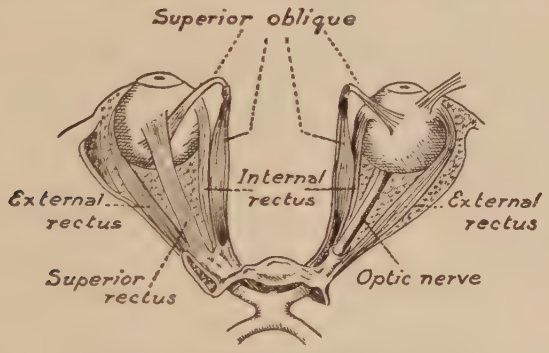

FIG. 156. — **Exterior muscles of eyeball.**

their positions, the superior, inferior, internal, and external recti muscles, are attached at one end to the sides of the eyeball and at the other end to the back of the orbit (Fig. 156). These, in the order named, turn the eyes upward, downward, inward, and outward. The other two, the superior and inferior oblique muscles, aid in certain movements of the recti muscles and, in addition, serve to rotate the eyes slightly. The movements of the eyeballs are similar to those of ball and socket joints.

Binocular Vision. — In addition to directing the eyeballs so that light may enter them to the best advantage from different objects, the

muscles also enable two eyes to be used as one. Whenever the eyes are directed toward the same object, an image of this object is formed on the retina of each. Double vision is prevented only by having the images fall on corresponding places in the two eyes. This is accomplished by the muscles. In each act of seeing, it becomes the task of the superior and inferior recti muscles to keep the eyes in the same plane, and of the external and internal recti muscles to give just the right amount of convergence. If slight pressure is exerted against one of the eyes, the action of the muscles is interfered with and, as a consequence, one sees double. The advantages of two eyes over one in seeing lie in the greater distinctness and broader range of vision and in the greater correctness of judgments of distance.

Visual Sensations. — The visual sensations include those of *color* and those of a *general sensibility to light*. Proof of the existence of these types of sensation is found in color blindness, a defect which renders the individual unable to distinguish certain colors when he is still able to see objects. Color sensations are the results of light waves of different lengths acting on the retina. While the method by which waves of one length produce one kind of sensation and those of another length a different sensation is not understood, the cones appear to be the portions of the retina acted on to produce the color. On the other hand, the rods are sensitive to all wave lengths and give general sensibility to light.

Visual Perceptions. — "Seeing" is very largely the mental interpretation of the primary sensations and the conditions under which they occur. For example, our ability to see objects in their natural positions when their images are inverted on the retina is explained by the fact that we are not conscious of the retinal image, but of the mind's interpretation of it through experience. Experience has also taught us to locate objects in the direction toward which it is necessary to turn the eyes in order to see them. In other words, we see objects in the direction from which the light enters the eyes. That the object is not always in that direction is shown by the image in the mirror. The apparent size and form of objects are inferences, and they are based in part upon the size and form of the area of the retina stimulated. We judge of distance by the effort required to converge the eyes upon the objects, by the amount of divergence of the waves entering the pupil, and also by the apparent size of the object.

The Lachrymal Apparatus. — Seeing requires that the light penetrate to the retina. For this reason all the structures in front of the retina are transparent. One of these structures, the cornea, on account of its exposure to the air, is liable to become dry, like the skin, and to lose its transparency. To preserve the transparency of the cornea, and also to lubricate the eyelids and aid in the removal of foreign bodies, a secretion, called *tears*, is constantly supplied.[1]

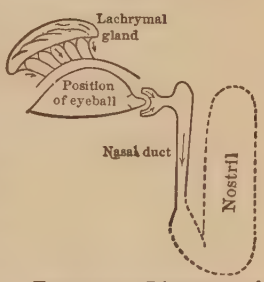

FIG. 157. — **Diagram of irrigating system of the eye.** After wetting the eyeball the tears may also moisten the air entering the lungs.

The lachrymal, or tear, glands are situated at the upper and outer margins of the orbits. They have the general structure of the salivary glands and discharge their liquid by small ducts beneath the upper lids. From here the tears spread over the surfaces of the eyeballs and find their way in each eye to two small canals whose openings may be seen on the edges of the lids near the inner corner (Fig. 157). These canals unite to form the *nasal duct*, which conveys the tears to the nasal cavity on the same side of the nose. When by evaporation the eyeball becomes too dry, the lids close reflexively and spread a fresh layer of tears over the surface. Any excess is passed into the nostrils, where it aids in moistening the air entering the lungs.

[1] The essential purpose of the tears is that of protection to the eyes. In addition to protecting them in the ways described in the text, they protect them to a considerable extent from attacks of germs. The eyes are further protected by the bony orbits in which they are placed, by the eyelids with their fringe of lashes, by the eyebrows, and by a sensitive membrane, called the *conjunctiva*, which lines the lids and covers the front of the eyeballs.

HYGIENE OF THE EYE

Because of the delicacy of the sense organs of sight, they are especially liable to two kinds of injury — that which comes from attacks of germs and that which results from strain of the eye muscles.

Eye Infections: How Spread. — An eye infection is a germ nest in this part of the body. The germs themselves and the poisons which they secrete irritate the delicate linings of the eyes and cause them to itch, smart, and burn. The eyes also become red, or inflamed, and frequently there is swelling of the lids and the formation of pus. The two most common of our eye infections are *pink eye* and *trachoma*, or granulated lids. Most eye infections are contagious from the fact that the germs causing the infections can pass from the eyes of those having them to eyes that are healthy. They are able to do this in the following ways:

1. By the common use of articles, such as towels and handkerchiefs, that are brought in contact with the eyes.

2. By means of water that comes in contact with the eyes of different people, such as the water in swimming pools. Water also spreads the germs when two or more persons use the same wash basin.

3. By the hands of those having eye infections coming in contact with the hands of others. For example, a child having sore eyes is very apt to rub them and, in this way, to get the germs on the fingers. If, in playing, the hands are clasped with those of some other child, the germs are transferred to this child. It now only remains for the second child to rub its eyes for the transfer to be complete.

Eye infections cannot be spread by simply looking at eyes that are diseased, as popularly supposed.

To Avoid Eye Infections. — This is done by avoiding the means by which the germs are spread, as explained above. Since it is almost impossible to have pupils at school observe all these conditions, it is usually best for those with serious eye infections to remain at home until the physician gets them under control. It is also an aid in the prevention of eye infections to keep the eyes from getting strained. Eyestrain lowers the local resistance (p. 400) of the eyes and makes it easier for all kinds of germs to get a start. This is illustrated by painful infections of the lids, called

Sties. — A sty is an infection at the root of an eyelash of the nature of a boil. It is exceedingly painful and the germs from one sty may cause others and these still others, so that the trouble may become continuous. Those having sties should get the eyes tested for glasses. The glasses, by relieving the strain, improve the local resistance of the lids so that the sty germs can no longer make successful attacks.

Eyestrain. — This may be defined as a disturbed and oversensitive condition of the eyes due to overwork of the eye muscles. As the ciliary muscles and the external eye muscles become sore from overuse, the circulation to the eyes is disturbed and all the nerves to the eyes become very sensitive. The result is a condition that causes the eyes to work at a great disadvantage and to waste much nervous energy.

Indications of Eyestrain. — The more common of the indications are as follows:

1. The eyes hurt from close work, such as reading, and there may be itching, smarting, and burning of the lids from only slight use.

2. The eyes cease to be clear and bright and the eyelids

and eyeballs look weak and show a tendency to become inflamed. There may also be frequent sties and tiny scales may form at the roots of eyelashes.

3. The eyeballs feel hard when pressed upon with the finger with lids closed, and are sensitive to pressure.

4. The eyes are sensitive to light and are much irritated by direct light, by the glare from snow, white buildings, cement walks, etc., and by the light from moving pictures.

5. There are tell-tale wrinkles about the eyes and upon the forehead and quite frequently an unnatural facial expression.

6. There are usually nervous disturbances, such as headache, nervousness, insomnia, peevishness, and the tendency to worry.

7. One with eyestrain frequently finds it hard to look another person in the eyes while talking to him.

Poor vision may or may not indicate eyestrain. In many cases of poor vision there is an absence of strain and often there is serious strain where the vision is perfect.

Causes of Eyestrain. — There is but one fundamental cause of eyestrain and that is *overwork of the eye muscles.* The overwork, however, is of different kinds and may be brought about in different ways. While most eyes are more frequently overworked by looking at near objects or by reading, some eyes are overworked and irritated by bright light, by looking at distant objects, especially if these be moving, and by bad positions in using the eyes. The fact that some eyes are more easily overworked than others is explained by the presence of defects in the eyes and by differences in the general health.

Eye Defects. — The more common of these are as follows:

1. *Hyperopia,* or long sight — a condition in which the

eyeball is too short for the focusing power of the lenses so that the image tends to fall back of the retina instead of upon it (Fig. *B*, 158).

2. *Myopia*, or short sight — a condition just the opposite of hyperopia. The eyeball is too long for the focusing power of the lenses. This causes light from distant objects to focus in front of the retina and to spread again before reaching the retina (Fig. *C*, 158).

3. *Astigmatism* — a condition in which one or both eyes fail to focus uniformly in their different parts, or meridians. From top to bottom, for example, the eye may focus normally, while from side to side, things appear more or less blurred. Astigmatism is the usual cause for indistinct vision when one has neither hyperopia nor myopia.

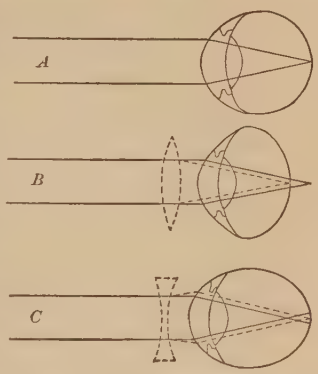

FIG. 158. — **Diagrams illustrating long-sightedness and short-sightedness**, and method of remedying these defects by lenses. *A*. Normal eye. *B*. long-sighted eye. *C*. Short-sighted eye.

4. *Imbalance* — a condition in which the two eyes do not work together as they should. One of the eyes may be slightly higher in the head than the other, or there may be something wrong with the external eye muscles or the way they are attached to the eyeballs.

The effect of each of these defects is to increase the effort necessary to vision and to cause the eyes to work at a disadvantage.

To Prevent and Relieve Eyestrain. — There are two practical methods of doing this. One is to lessen eye work by every means possible. The other is to build up, or

strengthen, the eyes so that they can more easily do the work devolving upon them. Working by the first method, we curtail unnecessary reading, avoid so-called "fancy work," omit night study, exercise care as to light, position, etc., and make a proper use of glasses that correct our eye defects. Working by the second method, we take special exercises for "toning up" the eye muscles (p. 273), bathe the eyes frequently, and build up the general health.

Eye Bathing. — Two kinds of eye baths which students in the author's hygiene classes have found very beneficial are the following:

1. *A fresh water bath* taken when one washes the face in the morning and which consists in flooding the eyes with pure, cold water. While bending over the wash bowl, water is thrown into the eyes with the hands and worked under the lids by opening and closing them. This causes a slight and momentary smarting.

FIG. 159.— Eye cup.

2. *A salt water bath* which is best taken from an eye cup (Fig. 159) and in the afternoon or evening. The salt solution should be strong enough to smart the eyes about the same as did the fresh water. It can be prepared in quantity and kept in a clean bottle on the dresser.

Eyes and the General Health. — It is a matter of common knowledge that the eyes get stronger as the health improves and weaker as the health declines. Good health aids muscle tone and strengthens the nerves, and healthful eye work depends upon both. Those having weak eyes should do everything possible to build up the general health.

When Glasses are Necessary. — Glasses are necessary when one, by using the methods suggested above, is unable to keep the eyes strong enough to avoid strain. They are also necessary when one has poor vision. Especially should one with poor vision from myopia get properly fitted glasses at the earliest moment. Myopic eyes when neglected nearly always become worse.

To Remove Foreign Bodies from the Eyes. — Foreign bodies imbedded in the eyeball should be removed by the oculist or the physician. Small particles of dust or cinder may be removed without the aid of the physician by taking proper care. First let the tears, if possible, wash the substance to the corner of the eye or edge of the lid, where it can be removed with a soft cloth. If it sticks to the ball or the under surface of the lid, it must first be located and then dislodged. Begin by examining the lower lid. Pull it down enough to expose the inner surface and, if the substance be there, wipe it off with the hem of a clean handkerchief. If it is not under the lower lid, we must turn back the upper lid in this wise. With the patient looking down, the lashes are seized between the forefinger and thumb of the right hand and the lid drawn downward and away from the eyeball, and then upward and backward over the end of a finger held on the lid for a fulcrum. The substance is now removed in same manner as from the lower lid.

Strong Chemicals in the Eyes. — Students in the laboratory frequently, through accident, get strong chemicals, as acids and bases, in the eyes. The first thing to do in such cases is quickly and thoroughly to *flood the eyes with water*. Any of the chemical which remains may then be counteracted by the proper reagent, care being taken to use a very dilute solution. To counteract an acid, use sodium bicarbonate (cooking soda), and for bases use a very dilute solution of acetic acid (vinegar). To guard against getting the counteractive agent too strong for the inflamed eye, it should first be tried on an eye that has not been injured.

Summary. — The afferent impulses that cause the sensation of sight are started by light waves falling upon a sensitized nervous surface in the back of each eyeball, called the retina. By means of lenses forming a part of the eyeball in front of the retina, light from different objects is focused and made to form images upon this surface. In this way the light makes an impression upon the retina somewhat similar to the object itself. This, the *image method of stimulation*, enables the mind to recognize and locate objects and quickly to become conscious of its surroundings. To keep the eyes healthy in all respects is one of the important problems of right living.

Exercises. — 1. What different things must happen in order to see objects?

2. Make a sectional drawing of the eyeball, locating and naming its main parts.

3. What portions of the eyeball reflect light? What absorb light? What refract light?

4. Show how the iris, the crystalline lens, the retina, and the cornea aid in seeing.

5. Trace light from a visible object to the retina.

6. What change occurs in the shape of the crystalline lens when we look from distant to near objects? From near to distant objects? Why are these changes necessary?

7. With two eyes how are we kept from seeing double?

8. What purposes are served by the tears? Trace them from the lachrymal glands to the nostrils.

9. What are eye infections? Illustrate. How are they kept from spreading from one person to another?

10. Define eyestrain. How is it caused? What are some of its indications?

11. Why should one with eyestrain want to avoid looking the person in the eyes with whom he is talking?

12. By what two general methods is eyestrain prevented? How does good health aid in its avoidance?

13. How do well-fitted glasses prevent eyestrain?

14. How do well-fitted glasses save the nervous energy? How do they prevent sties?

PRACTICAL WORK

To Illustrate Simple Properties of Light. — 1. Heat an iron or platinum wire in a clear gas flame. Observe that when a high temperature is reached it gives out light or becomes luminous.

2. Cover one hand with a white and the other with a black piece of cloth, and hold both for a short time in the direct rays of the sun. Note and account for the difference in temperature which is felt.

3. Stand a book or a block of wood by the side of an empty pan in the sunlight, so that the end of the shadow falls on the bottom of the pan. Mark the place where the shadow terminates and fill the pan with water. Account for the shadow's becoming shorter.

4. Place a coin in the center of an empty pan and let the members of the class stand where the coin is barely out of sight over the edges of the pan. Fill the pan with water and account for the coin's coming into view. Show by a drawing how light, in passing from the water into the air, is so bent as to enter the eye.

5. With a convex lens, in a darkened room, focus the light from a candle flame so that it falls on a white screen and forms an image of the candle. Observe that the image is inverted. In a well-lighted room focus the light from a window upon a white screen. Show that, as the distance from the window to the screen is changed, the position of the lens must also be changed. (Accommodation.)

FIG. 160. — **Diagram** for proving presence of the blind spot.

To Prove the Presence of the Blind Spot. — Close the left eye and with the right gaze steadily at the spot on the left side of this page (Fig. 160). Then starting with the book a foot or more from the face,

move it *slowly* toward the eye. A place will be found where the spot on the right entirely disappears. On bringing it nearer, however, it is again seen. As the book is moved forward or backward, the position of the image of this spot changes on the retina. When the spot cannot be seen, it is because the image falls on the blind spot.

Dissection of the Eyeball. — Procure from the butcher two or three eyeballs obtained from cattle. After separating the fat, connective tissue, and muscle, place them in a shallow vessel and cover with water. Insert the blade of a pair of sharp scissors at the junction of the sclerotic coat with the cornea and cut from this point nearly around the entire circumference of the eyeball, passing near the optic nerve. Spread open in the water and identify the different parts from the description in the text. Open the second eyeball in water by cutting away the cornea. Examine the parts in front of the lens.

FIG. 161. — **Model** for demonstrating the eyeball.

To Illustrate Accommodation. — Paste together the ends of a strip of stiff writing paper (two by five inches), making a ring a little less than three inches in diameter. This is to represent the crystalline lens. Now paste a piece of thin paper (two by seven inches) upon a second strip of the same size, leaving an open place in the middle for the insertion of the paper lens. A flexible piece of cardboard (three by twelve inches) is now bent into the form of a half circle and to its ends are fastened the strips of paper containing the ring. Make a small hole in each of the four corners of the bent cardboard. Through these holes pass two loops of thread, or fine string, in opposite directions, letting the ends hang loose from the cardboard.

When everything is in position, the tension from the cardboard flattens the paper lens, while pulling the strings releases this tension and permits the lens to become more rounded. With this simple device the changes in the curvature of the lens for near and distant vision are easily shown.

CHAPTER XXX

OUR CONFLICT WITH GERMS

One of the discoveries of modern science is that the human body is in continuous conflict with minute organisms, the so-called germs of disease. In order that our methods of living may assist the body and not the germs in this conflict, we must understand the nature of our enemies and our means of defense.

Some Facts about Germs. — 1. Although scientists have discovered about 1500 different kinds of microörganisms, or germs, there are only about 60 kinds that can live within the human body and do it harm.[1]

2. Germs that injure the body are of two kinds — animal germs that are called *protozoa* and plant germs that are called *bacteria*. Most of our diseases are caused by bacteria.

3. The natural home for most of the germs that cause disease is the human body. Although some of them can live in water and in filth for a while and can even increase in numbers in milk and other foods, most of them develop and live in people themselves.

4. Germs may exist in the human body in either of two conditions — one in which they are active in reproducing themselves and in causing us trouble, and another in which

[1] Germs injure the body by the destruction of cells and by the secretion of poisons, called toxins, which are spread over the body by the blood. The worst effect in most cases is from the toxins.

they are inactive, or latent, and are not reproducing or causing us trouble. The condition, called *germ freedom* (p. 22), is usually one in which the germs are latent.

5. Germs developing in the body of one person are usually able by some means to pass to the bodies of others. The diseases which they cause are, on this account, contagious.

Our Methods of Defense. — We have at least five good ways of fighting, or opposing, our germ enemies, as follows:

1. By keeping up good local resistance.
2. By keeping up good general resistance.
3. By attaining specific resistance.
4. By expelling from the body established infections.
5. By avoiding conditions that enable the germs to spread from one person to another.

Our Local Resistance. — This, as already explained (p. 108), means the power of any part of the body to resist attacks of germs, and has special reference to the body surfaces — the skin and the mucous linings of the nose, throat, lungs, eyes, mouth, stomach, and intestines. The problem of keeping up a good local resistance in any part is solved in each case by *keeping the part healthy*. Methods of doing this have been described in the preceding pages in sections dealing with local resistance (consult index).

General Resistance. — This condition has also been explained (p. 109). It is the power of the body as a whole to resist attacks of all kinds of germs. It depends upon the general health, becoming better as the health improves and *vice versa*. It is looked after properly when, through right living, we keep up all of our health foundations (p. 22) and avoid the indiscretions that bring down the health for short intervals. Short periods of low general resistance may give the germs just the chance they need.

Specific Resistance. — This is the power of the body to resist the germs of some particular disease, such as measles. It depends upon substances in the blood and other fluids, called *antibodies*, which in some cases counteract the germ poisons and, in others, destroy the germs themselves.[1] As long as we are well supplied with antibodies that oppose some kind of germs, we are immune to the disease which the germs cause. To get specific resistance to any disease, we must in some way get its kind of antibodies. There are three ways of doing this, as follows:

1. By having the disease itself.
2. By vaccination.
3. By developing the antibodies in lower animals and transferring them to ourselves.

To Obtain Antibodies by Having the Disease. — In having a germ disease that develops immunity, the body becomes very active in a special way, which is called its *reaction*. As a result of the reaction it develops the antibodies, and when it gets enough of them, the germs can no longer injure it. This is why one recovers from the disease after having had it for a certain time, although there are germ diseases, such as tuberculosis, in which this does not occur. The objection to getting antibodies by having the disease is that the method is too severe and dangerous.

Antibodies by Vaccination. — By this method a reaction is excited similar to that of the disease itself, but milder, by the introduction of a substance called a *vaccine*. The

[1] The three main kinds of antibodies are named *antitoxins*, *agglutinins*, and *lysins*. The first counteract germ poisons, the second cause the germs to collect in small masses, or clumps, and to be more easily destroyed by the white corpuscles, and the third destroy the germs by dissolving, or digesting, them.

vaccine is a preparation from the germs that cause the disease. It may contain the living germs in a mild form or it may have the germ toxins, and these may be either in a free state or in the bodies of dead germs.[1] The mild reaction from the vaccine causes the body to develop antibodies as does the disease itself, though not in such vast amounts. As a consequence, immunity obtained in this way does not last so long as when obtained by having the disease.

When Vaccination is Necessary. — There is only one disease against which universal vaccination is urged at the present time. This is the dangerous and widely prevalent disease, smallpox. Although smallpox frequently occurs in a mild form, it can change quickly from the mild to the dangerous type. *Every one should be vaccinated early in life against smallpox.* He should also be revaccinated during epidemics of the disease if it has been more than five years since the last successful vaccination.

Vaccination against typhoid fever is necessary whenever there is danger, as in living in a community where the disease is prevalent, of getting the germs into the body. Vaccination against hydrophobia is given only when one has been bitten by a rabid animal or has been otherwise exposed. As to vaccination against the "flu," colds, pneumonia, and other diseases, one must be guided by the advice of his physician.

Antibodies from the Lower Animals. — By vaccinating horses and other animals, they can be made to produce antibodies in the case of certain diseases, as do people. To get these from the animal, some of its blood must be drawn

[1] Smallpox vaccine contains weak living germs obtained by vaccinating cattle with the germs of cowpox. Typhoid vaccine contains dead typhoid germs and the germ poisons. Diphtheria vaccine contains only the germ poisons.

and allowed to coagulate (p. 33). The serum which separates from the clot is very rich in antibodies. This is carefully saved for injection under the skin of the patient. Such serums are of great value in the treatment of diphtheria, tetanus, or lockjaw (p. 288), and a few other diseases. They aid the body in fighting germs by supplying antibodies already prepared.

The Problem of Infections. — Any place in the body where germs are living and growing is called an *infection*. Since the germs from one place can spread through the blood to other places, infections are referred to as primary and secondary. A *primary infection* is a place where germs entering the body first get established. A *secondary infection* is a place that has become infected from a primary infection. The primary infections are mostly in the skin and mucous linings, while the secondary infections are more deep-seated, being in the heart and blood vessels, bones, glands, etc. The primary infections are also more easily cured and less dangerous than the secondary.

On account of the danger of germs spreading from one place to another, an infection anywhere in the body always presents a serious problem. Especially is it important to get rid of primary infections before they have time to start secondary infections.

Medical Aid for Infections. — In nearly all cases, the curing of an infection is a problem for the physician, although keeping up good general resistance is a great aid. He can employ different kinds of medicines for this purpose and also resort to surgery if this be necessary. We must also have the services of the physician in locating infections that are deep-seated and, through him, the advantage of X-ray pictures and other means of diagnosis.

The Spreading of Germs. — The only known way by which disease in one person can cause disease in another is by the passage of germs. There are at least five important ways by which germs are spread from one to another, as follows:

1. *By contact.* This includes direct contact of one person with another, as in hand shaking and kissing, and indirect contact, where two persons handle or touch the same object.

2. *By the air.* Germs that attack the air passages are thrown out in a fine spray by coughing, sneezing, and loud laughing and talking, where they can be breathed by others, as already explained (p. 113).

3. *By foods.* Germs getting into foods may live there for some time and enter the body with it. Milk very frequently spreads disease in this way. Thorough cooking, of course, destroys the germs in food.

4. *By water.* Water that has been rendered impure from decaying animal or vegetable matter is often a carrier of germs (p. 177). On this account, water collected by surface drainage is very dangerous. Impure water is rendered harmless by thorough boiling.

5. *By insects and other animal forms.* Insects, such as mosquitoes, that suck our blood, and insects, such as flies, that eat our food, are our worst enemies in this respect. Relentless war should be waged on both mosquitoes and house flies.

Methods of Fighting Mosquitoes. — Malaria, yellow fever, and other diseases that attack the blood are spread through mosquitoes. A mosquito sucking the blood of a malarial patient (Fig. 162) first infects its own body. Later it will bite a well person, and in so doing will put in the living germs. Good health in many communities

depends upon the wholesale destruction of mosquitoes. This is accomplished by the following methods:

1. The drainage of bodies of water in which mosquitoes lay their eggs and in which their larvæ develop.

2. By covering with crude oil or kerosene bodies of water that cannot be conveniently drained.

3. By stocking bodies of water too large for drainage or for oiling with suitable varieties of fish. Fresh water perch and sunfish are especially valuable for this purpose.

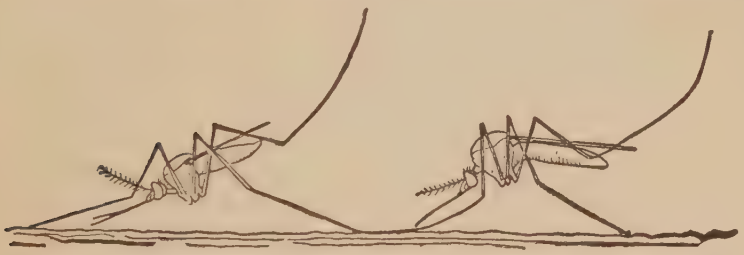

FIG. 162. — **Mosquitoes** in resting position. (From Howard's *Mosquitoes.*) On the left the malarial mosquito (*Anopheles*); on the right the harmless mosquito (*Culex*).

While these methods are being applied, the greatest care should be taken to prevent both the sick and the well from being bitten by mosquitoes. This includes the thorough screening of the places where the sick are cared for and where the well sleep or rest.[1]

To Destroy House Flies. — The most effective ways of fighting these enemies are the following:

[1] One of the greatest health triumphs of all time was the ridding of the Panama Canal Zone by the Americans of yellow fever and malaria, preparatory to the construction of the great canal. Twice had the French undertaken this task and failed on account of the sickness of the workmen. (They were working before the time when it was known that malaria and yellow fever were spread by mosquitoes.) With the wholesale destruction of mosquitoes by the Americans, these diseases could not be spread from one to another and so ceased to be a menace.

1. *By the destruction of their breeding places.* Although almost any kind of filth will, in warm weather, hatch out the eggs of flies and cause their larvæ (maggots) to develop, the manure heaps from stables seem to be most suitable for this purpose. On this account, removal from the stable and barnyard of all manure as fast as it is produced is the most effective single method of doing away with flies.

2. *By the use of large outdoor fly traps.* Boys can easily build these traps, and catching flies in them is almost as interesting as trapping for game.

3. *By the use of "fly swatters."* This is the very best way of killing the few annoying flies that get into the house in spite of the screens which should be on the windows and doors of every home in the summer.

The "fly swatter" is also valuable in getting rid of the few flies that would otherwise live through the winter by getting into our homes. Every winter fly that is destroyed prevents the thousands of flies that would result the following summer from the rapid methods by which flies propagate their young.

Germ Fighting through Cleanliness. — Filth of almost any kind supplies food for germs and is a means of keeping them alive outside of the body. In this way it aids in the transfer of germs from person to person and from one part of one person's body to another part. Dirty hands are, on this account, dangerous germ spreaders, while hands that are scrupulously clean are sanitary. The habit of washing the hands before meals, and the habit of washing them after going to the toilet, should be formed very early in life. Next to clean hands come the clean face and neck and the body as a whole and, after these, clean clothing. But we must not stop with our bodies. We should live in a clean house, sleep in a clean bed, and surround our-

selves with a clean and sanitary environment. Especially should conditions that affect the purity of our drinking water receive the most careful attention.

The Water Supply. — Since water readily takes up and holds the impurities with which it comes in contact, it should be exposed as little as possible in the process of collecting. Where cistern water is used, care must be taken to prevent filth from the roof (Fig. 163), water pipes, or soil from getting into the reservoir. Water should be collected from the roof only after it has rained long enough for the roof and pipes to have been thoroughly cleaned. The cistern should have no leaks (Fig. 164), and the top should be tightly closed to prevent the entrance of small animals and rubbish.

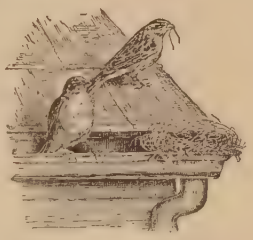

FIG. 163. — **Contamination of cistern water** by birds nesting in the gutter trough.

Shallow wells are to be condemned, as a rule, because of the likelihood of surface drainage (Fig. 164), and water from springs should, for the same reason, be used with caution. Deep wells that are kept clean usually may be relied on to furnish water free from organic impurities, but such water often holds in solution so much of mineral impurities as to render it unfit for drinking. The presence in water of any considerable quantity of the compounds of iron or aluminum makes it objectionable for regular use.

The Human Carrier. — Investigations show that people apparently well may have dangerous germs within or upon their bodies which they can communicate to others. These may be left-over germs from some disease, like typhoid fever, from which they have recovered, or they may be germs of some disease which they have never had. Such

people are called "carriers." They are a menace to those with whom they associate, although usually innocent of the fact themselves. An example of this is the diphtheria carrier whom we sometimes have in our public schools.[1]

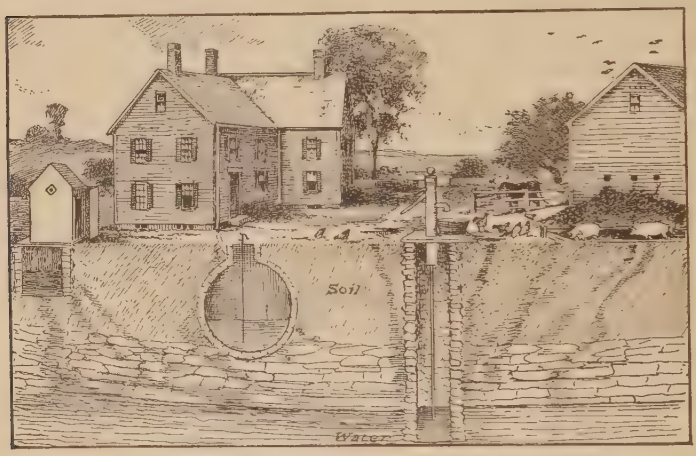

FIG. 164. — **Sources of contamination of cistern and well water.** Illustration shows liability of contamination from surface drainage and from entrance of filth at top.

The Method of Isolation. — One of the oldest known methods of preventing the spread of germ diseases is that of keeping the well and the sick separated. Distance presents a barrier which the germs are unable to cross, except through the agency of carriers. The principle may be applied when there are possibilities of contagion as well as when danger is known definitely to exist. An instance of this is the matter of staying away from public gatherings during an epidemic of some disease.

[1] In any school where there are frequent cases of diphtheria, there are very probably carriers of diphtheria germs among the children. Physicians are able to detect such carriers by making cultures from the throats of all the children in the school.

Summary. — In our methods of living we must take into account the ever present conflict between the human body and the germs that cause disease. We must so live that we assist our bodies and not the germs in this conflict. We must keep up good local resistance at all our body surfaces, we must maintain good general resistance, we must acquire specific resistance by approved methods, we must rid ourselves of established infections, and we must avoid conditions that aid in the spread of germs from one to another.

Exercises. — 1. How do disease germs differ from the other kinds? Where is their natural home?

2. How does local resistance differ from general resistance?

3. Upon what does good general resistance depend? How is it brought down for short intervals? What is the danger of this?

4. Define specific resistance. In what three ways is it obtained?

5. How does having a germ disease keep us from having it again? Explain vaccination.

6. When should one be vaccinated for smallpox? When for typhoid fever? When for hydrophobia?

7. How do we get antibodies from the lower animals? Why are the preparations containing them called serums?

8. What is an infection? How do the primary differ from the secondary? Why must all infections be cured as soon as possible?

9. Why is an infection in the mouth more dangerous than an infection of the skin?

10. In what different ways are germs spread from one person to another? How can all of these be avoided?

11. How do house flies spread germs? In what effective ways may we destroy house flies?

12. Explain how destruction of mosquitoes made possible the construction of the Panama Canal.

13. Discuss value of cleanliness in preventing spread of germs.

14. Describe a method of collecting pure cistern water.

CHAPTER XXXI

RIGHT LIVING IN ITS BROADER PHASES

RIGHT living means much more than keeping healthy, though we have limited our discussion so far to this idea. It means making the most of life or living in the fullest and truest sense. It includes, for one thing, the provisions that all must make for their daily needs.

Right Living as Regards our Maintenance. — A maintenance means more than enough to satisfy one's needs when conditions are favorable. Occasions are frequent when, from sickness, non-employment, or other causes, one is unable to earn money. To tide over such times we must have a surplus — money in the bank, property that can be sold, or property upon which money can be borrowed. To provide a maintenance, then, one must have along with his ability to work and his industry, the quality which we call *thrift*, a quality often not appreciated because misunderstood.

The Meaning of Thrift. — Thrift is not only the ability to save money, but also the ability to spend it profitably. It means both spending and saving on the basis of what is best. The thrifty person will spend and spend freely when he knows that what he purchases is of more value to him than the money which he pays out. He is neither stingy nor miserly in his tendencies, but understanding the value of money and his need for a surplus, he uses what he has to the best advantage. The thrifty folk are among our best citizens, and most encouraging is the nation-wide development of thrift as indicated by the increase in the number of safety-bank deposits in the last few years.

Some Thrift Rules. — That thrift means about the same as sensible living, is indicated by the following rules, quite generally accepted, for "getting ahead":

1. Keep up the health. Poor health entails extra expense and stops the daily wage.

2. Limit expenditures to essential needs — those related to health, efficiency in a broad sense, and to education.

3. Avoid alcohol, tobacco, coffee, tea, soft drinks, and other substances that waste money, and often health, and give no substantial return.

4. Find pleasure in the simple and wholesome things of life — those that make slight draft upon the purse and none upon health.

5. Keep down the false pride that would make one live beyond his means.

6. Acquire efficiency in more than one line of work. This will often enable one to avoid loss from lack of employment and to use his leisure moments to good advantage.

7. Judiciously invest the savings. "Money at interest is a good silent partner," but a poor investment may remove one's surplus entirely.

Right Living and Character Formation. — Just as we are subject in our ordinary methods of living to conditions that change our shape (Chapter XX), we are constantly exposed to conditions that mold our character. The key to character formation is habit formation, and we can determine our progress at any time by making an inventory of our habits and tendencies. One may be said to be living right as far as his character is concerned when, being good in the first place, he is becoming better each year that he lives.

Desirable Traits of Character. — By character is meant the usual way that one reacts to people and to different situations that present themselves. When we analyze the

good character, we find such traits as honesty, tact, courtesy, dependability, courage, thoroughness, perseverance, fairness, earnestness, and conscientiousness. One with such qualities must command respect in his community, though character and reputation are not identical. "Character is like an inward and spiritual grace of which reputation is, or should be, the outward and visible sign."

Value of Good Character. — This is best expressed by the word "priceless." Good character is the basis for successful coöperation of people in all of the affairs of life and by some is ranked next in importance to life itself. Men of character can be trusted, they will always do their part, and they will not take a mean advantage under any circumstances. Such men are needed everywhere, but most of all, perhaps, in positions of public trust.

Right Living and the Making of Friends. — There is something wrong about one's living if he is not cultivating friendship wherever he goes. "We need friends to help us stand the trials of life," and we also need friends to make each day fuller and happier. With character, friendship is a valuable aid to coöperation and success in life, and its cultivation can easily be made a matter of the daily routine. Every phase of life — the home, school, store, shop, and farm — all afford opportunity for the making of friends. The general method is well stated in the proverb, "He that hath friends must show himself friendly," though the basis for enduring friendship is good will and genuine character. The one who can himself be a good and true friend will find little trouble in keeping the friends that he makes.

Living and Learning. — While physical growth ceases somewhere between the ages of twenty and twenty-five, there is a form of mental growth, called learning, that can go on as long as one lives. This fact should be taken into

account by everyone in his living and ample provision made for the continuous "reconstruction of old facts and experiences in the light of new situations." The advantages are too apparent to require mentioning. Certainly one is not living as he should when he lets his education stop at an early period, say when he graduates from school. "It is false," says Forel, "to believe that we have to learn only in youth; we have never finished."

Right Living and the Habit-Forming Drugs. — Attention has been called at different places in our course to substances, such as alcohol, the nicotine of tobacco, and the caffeine of tea and coffee, that have the effect of developing an artificial appetite, or craving, that leads to their continued use. Since the effect of these is generally harmful and since they tend to engraft themselves upon communities through their effect upon individuals, they present a two-fold problem in the matter of our living. A person may be injured by the use he makes of them himself, and he may be injured through their effect upon some member of his family or upon society in general. Right living precludes their use on both grounds.

Of the above-named substances, alcohol is decidedly the worst, both from the individual standpoint and the standpoint of society. It is fortunate, therefore, that we have a national law prohibiting the manufacture and sale of alcoholic beverages. This law should be upheld by all.

Right Living in a Democracy. — Living in a country in which "the power to govern is derived from the governed," places a greater responsibility upon the citizens than does living in a country where there is less individual freedom. Since "the people are the government," they should so live that their influence is toward stability and the maintenance

of law and order and not in the opposite direction. They should be good citizens in all respects, thinking much of their country's welfare and being willing to work and sacrifice for its advancement. If called to serve in public office, they should feel a *special responsibility* in serving honestly and for the public good. Through such living by a sufficient number, the people's government cannot fail.

Right Living in the Spiritual Sense. — A danger confronting everyone is that of becoming so absorbed in obtaining the things needed for living and in the comforts and pleasures derived from their use, that he permits the higher life, or "the life of the spirit," to be crowded out. This is *materialism in its practice* and is unhealthy, to say the least. It is just as true to-day as it was two thousand years ago that "life is more than meat and the body than raiment," that "a man's life consisteth not in the abundance of the things that he possesseth," and that "to be carnally minded is death, but to be spiritually minded is life and peace." With this higher phase in mind, we can all agree with Sir John Lubbock that "the most important thing to learn in life, is how to live."

Summary. — Right living means more than keeping in good health. We must realize the opportunity of living *in the present day and age* and make the most of it. We must so live as to have a dependable maintenance, provide for the development of character, make numerous and fast friends, go on and on with our learning, and avoid enslavement by habit-forming drugs. Living in a democracy puts a special responsibility upon the individual and living in accord with the "laws of the spirit" would raise our ideal still higher. All this means that we must continue our study of *how to live*.

Exercises. — 1. What aims of right living were set forth in Chapter IV?

2. From your study of this chapter what other aims would you add to the list?

3. Discuss the question of one's maintenance. Need the children of the rich be concerned with this question? Why?

4. State the two phases of thrift. Is there a need for lessons on thrift in our public schools?

5. Why do we consider "honesty the best policy" in the matter of getting ahead?

6. Distinguish between character and reputation. Which is the more important? Why?

7. How is one's life made better by having friends? How are friends made? How kept?

8. Why does right living require that we keep on learning?

9. Why must citizens in a democracy give more attention to their living than citizens in a monarchy?

10. What do we mean by right living in the spiritual sense?

11. Write a short essay on the topic, "Learning to Live."

SUMMARY OF PART II

For the maintenance of life the needs of the cells must be supplied and *the body as a whole must be brought into proper relations with its surroundings*. The last-named condition requires that the body be moved from place to place; that its parts be controlled and coördinated; and that it be adjusted in its various activities to external physical conditions. To accomplish these results there are employed:

1. The skeleton, or bony framework, which preserves the form of the body and supplies a number of mechanical devices, or machines, for causing a variety of special movements.

2. The muscular system, which supplies the energy necessary for executing the movements of the body.

3. The nervous system, which (*a*) controls and coördinates the various activities and (*b*) provides for the *intelligent* adjustment of the body to its environment. (Review Summary of Part I, page 223, and consult Fig. 92, page 222.)

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